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TRI-NITRO-GLYCERIN.

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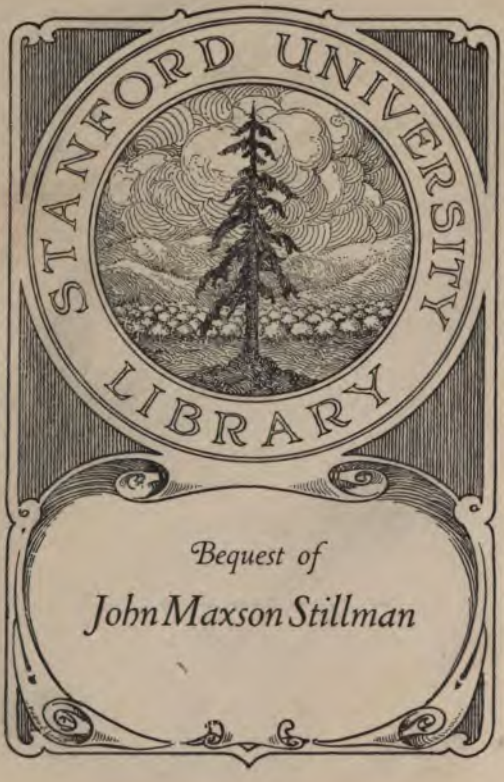

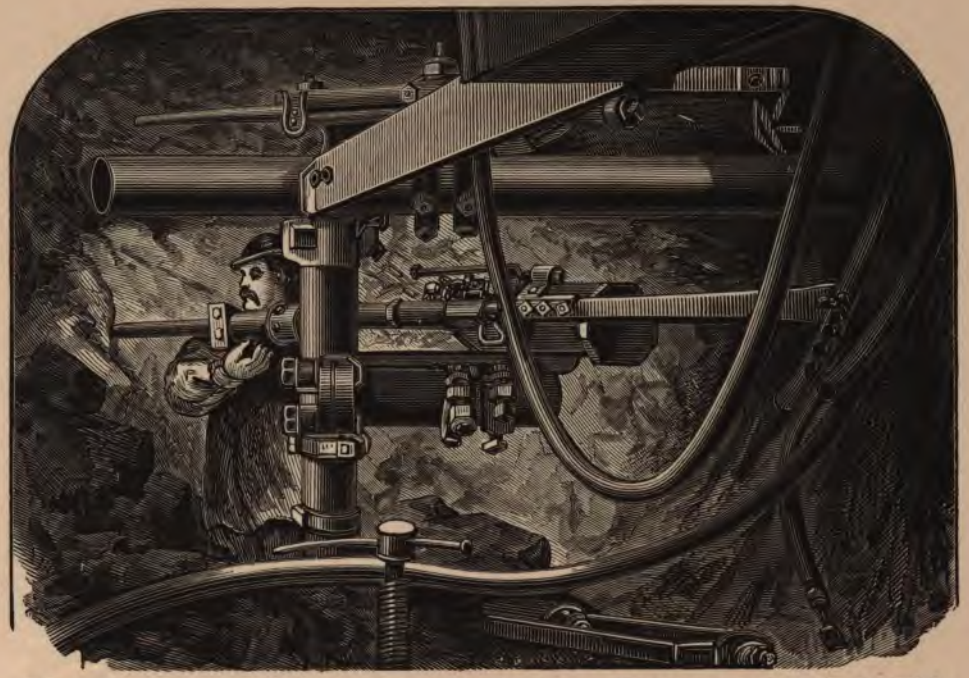

West Heading, with Burleigh Drill, from Photograph taken with Magnesium Lights.

TRI-NITRO-GLYCERIN,

AS APPLIED IN THE

HOOSAC TUNNEL,

And to Submarine Blasting, Torpedoes, Quarrying, etc.; being the Result of Six Years' Observation and Practice, during the Manufacture of upwards of Five Hundred Thousand Pounds of this Explosive; Mica Blasting Powder, Dynamites; with an account of the various Systems of Blasting by Electricity; Priming Compounds, Exploders, Electrical Machines; etc., etc., etc.

BY

GEORGE M. MOWBRAY,

Operative Chemist.

With Thirteen Illustrations, Tables and Appendix.

[illegible]

Third Edition—Re-written.

NEW YORK:

D. VAN NOSTRAND.

NORTH ADAMS, MASS:

JAMES T. ROBINSON & SON, PRINTERS AND BINDERS,

Transcript Building, Bank Street.

1874.

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To

WALTER SHANLY, M. P.

Indebted to you for the resources which have enabled me to investigate the properties of Nitro-Glycerin, and render its manufacture a commercial success, permit me to dedicate the following pages in token of my appreciation of the indomitable energy, admirable organization, integrity of purpose, and engineering talent which have rescued the Hoosac Tunnel from the mire of politics and rendered it an engineering success; notwithstanding extraordinary impediments of flood, water fissures, strikes, jealousy and indifference on the part of those chiefly interested, that must have been most disheartening to your mind, and challenged a resolution and resources seldom combined with the abilities you have shown in this work. Our relations during the past five years having been without a ripple, render this, my simple duty, an agreeable task.

GEORGE M. MOWBRAY.

PREFACE TO THIRD EDITION.

Since the last edition of this work, the withdrawal of a suit and promised payment of costs by the president of the United States blasting oil company, now defunct, renders superfluous any details of the litigation I have had to sustain, in order to protect the public against an attempt to monopolize Sobrero's discovery of nitro-glycerin. And further, since it is now admitted that this explosive is the most powerful known to man, being in fact "the ideal of portable force," it seemed to me I might properly omit the anecdotes of early difficulties encountered in its introduction to the Hoosac tunnel; the miners' prejudices have now disappeared, and those who obstructed its use have since threatened to strike, if deprived of tri-nitro-glycerin for a month, in order to institute a strict comparative test with powder; men who for thirty years lived through powder smoke, in their mining operations, declaring it unfit for a human being to endure in deep shafts or long tunnel. These omissions have enabled me to re-write the work, to add tabulated results, and give a resume of the old world's experience and experiments with gun cotton, so that, if less interesting to the general reader, the substituted matter is perhaps of more value to the engineer, contractor and projectors of international improvements, which cannot be carried through in any reasonable period without this powerful agent. I am more than ever sensible that my exacting occupation unfits for literary success, to which this book has no pretensions.

GEO. M. MOWBRAY.

North Adams, Mass., June, 1874.

PREFACE TO FIRST EDITION.

A paper read by request at the Albany Institute, was the germ of the following pages; its publication in this form, I considered would furnish engineers, contractors and railroad directors, who occasionally apply to me for particulars as to the use of nitro-glycerin in the Hoosac tunnel, with detailed information impossible to condense in a business letter. Hurriedly composed during the spare hours of a manufacture involving grave responsibility, the writer weighted with the additional task of defeating an attempt to monopolize the use (not the manufacture) of nitro-glycerin throughout the United States, whilst the subject itself, "Explosives, and firing mines by Electricity," constantly demanded experimental research, this work has not the arrangement nor the completeness I could desire; but the author hopes it will create a more favorable regard in the public mind, towards the most powerful blasting agent known, by correcting errors in respect to its properties, and the casualties attending its use; and assist miners and contractors to a more intelligent acquaintance with some of the materials the present advanced state of engineering progress has brought into practical use.

GEO. M. MOWBRAY.

North Adams, Mass., June, 1872.

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CHAPTER I.

SUCCESS VERSUS FAILURE—COMMISSIONERS AND ENGINEERS OF MASSACHUSETTS FURNISHING OPPORTUNITY—PREJUDICE, DIFFICULTIES—COMPARISON OF ECONOMY AND PROGRESS—CONTRACTOR MYERS' EXPERIENCE—DIFFICULTIES OF INTRODUCING NITRO-GLYCERIN SAME AS WITH PETROLEUM—ARRIVAL OF GLONOIN OIL AT NEW YORK—EXPLOSIONS AT WYOMING HOTEL, ASPINWALL AND SAN FRANCISCO—INVESTIGATIONS BY SCHONBEIN—IMPROVEMENT OF ACIDS USED IN GROVE'S CONSTANT BATTERY LEAD TO DISCOVERY OF GUN COTTON—CONTROVERSY AS TO ITS COMPOSITION LEADS TO DISCOVERY OF NITRO-MANNITE, NITRO-DEXTRIN, NITRO-GLYCERIN AND NITRO-SUGAR, BY ASCAGNE SOBRERO—NITRO-SUGAR PROPOSED BY LEWIS THOMPSON FOR RENDERING GUNPOWDER IMPERVIOUS TO MOISTURE.

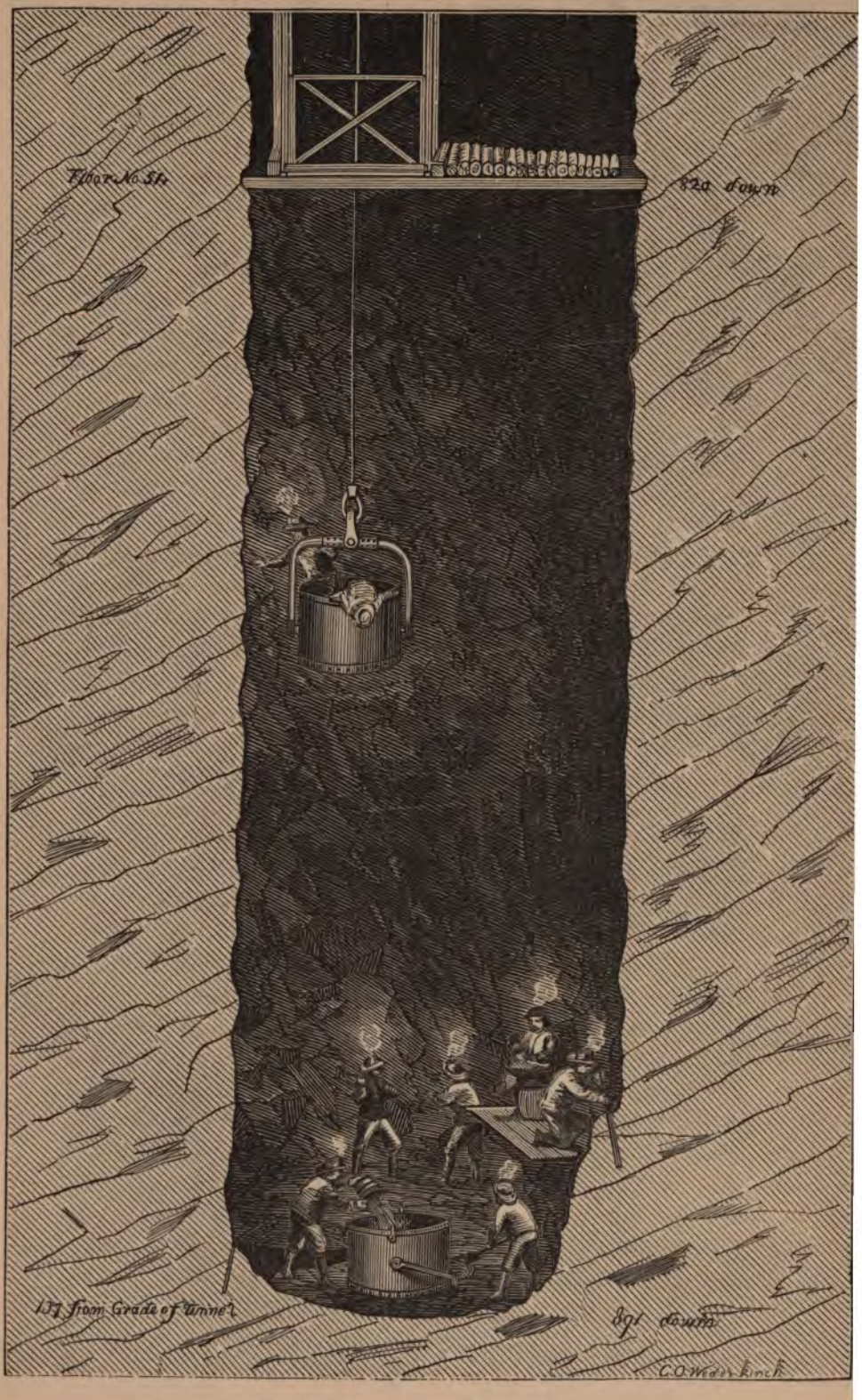
THIS book is only a trifle—it narrates a success, where England, Germany, France, Austria, Denmark, Rome and Switzerland have failed; that is all there is in it. Americans are indebted for this success, where other nations failed, and actually tabooed the use of nitro-glycerin, mainly to the opportunity furnished the writer, by the Commonwealth of Massachusetts, through her commissioners, Alvah Crocker, Tappan Wentworth, and S. W. Bowerman, under the supervision of engineers Benjamin Latrobe, Thomas A. Doane, W. P. Granger, E. S. Philbrick, Benjamin D. Frost, and their assistants.

At the time, 1866, be it remembered, nitro-glycerin was associated in the popular mind with terrible accidents, the

memory of which caused it to be described as "the most treacherous, dangerous compound known to mankind,"—the press noticing it as, "nitro-glycerin again;" the reader can therefore appreciate the moral courage of the gentlemen above named who, aware of the responsibility they incurred, determined that a fair trial of its merits, properties and value as a mining agent, should be had. Its power none disputed—it was the ability to control it, during manufacture, whilst teaming over rough roads, in magazines, or final handling in a tunnel, two miles from daylight, where miners were crowded amid open flaring lamps, glimmering candles, steel picks and drills, fuses and powder, laden cars rushing to and fro, with occasional thunder-storms flashing and raging outside, unbeknown to the men working at their arduous tasks a thousand feet below the mountain top they were perforating—these were the conditions implied, superadding the prejudice of the workmen, who almost wished their prejudices might prove well founded, and thus be well rid of an imaginary increased source of danger.

Since the introduction of this explosive as a substitute for gunpowder in the Hoosac tunnel, accidents from explosion have diminished two-thirds of the previous average rates, progress has advanced from the rate of sixty-one feet per month in September, 1868, under state supervision, to four hundred feet per month in September, 1873, under contract, being sixfold; and to-day, February, 1874, tri-nitro-glycerin delivered from the factory at $1.00 per pound, possessing an admitted force of ten times that of the best mining powder, is a reduction in cost of explosive force in favor of nitro-glycerin over powder of thirty-three per cent.; that is, mining powder must be delivered to the miner at $2.50 per keg of twenty-five pounds, in order to equal the force contained in two and one half pounds of nitro-glycerin sold for $2.50, without taking into account the greater rapidity of the work, the saving of one-third in the labor of drilling, of one-third the steel, and one-third the fuel to impel the drilling machines. Add to this that nitro-glycerin will blast out holes four times the depth of powder-charged holes, and the saving of time in removing and replacing the drilling machines is apparent, and its usefulness to the contractor indisputable.

As some credit is due to those who first appreciated these



Sinking the Central Shaft.

facts, I extract from an able and interesting paper read before the American Society of Civil Engineers, on the 4th of March, 1868, by Edward P. North, C. E., and printed in Lieutenant Commander J. S. Barnes', U. S. N., *Submarine Warfare*, (D. Van Nostrand, 1869) page 218.

"Mr. Myers, our contractor, who has had a great deal of experience in blasting operations, says that in hard dry ledges he thinks fully double the speed could be made with glycerin than with powder, and in wet ledges fully four times the speed with the same force of men. * * * A hole can be loaded and fired in much less time with nitro-glycerin than with powder, and, as a matter of economy, he would prefer to pay $1.12½ per pound for nitro-glycerin, to having powder *given to him*, for hard dry ledges; or to having $10 *per keg given to him* for all the powder he would use in blasting wet ledges. He also thinks nitro-glycerin much safer than powder."

In 1859, the writer of these pages was engaged in the introduction of petroleum from the then just discovered wells of E. L. Drake, W. Barnsdell, Jonathan Watson, James Parker, David Crosly, and others, in Pennsylvania, meeting, stemming, and overcoming the prejudices of the coal oil distillers, and inducing them to abandon their opposition to petroleum, and become ranged in the ranks of those engaged in developing this wonderful industry. Within twelve months the product of eighty-four wells streamed from the oil region to New York, Boston, Pittsburgh and Chicago, whilst the torrent of prejudice, conflicting interests and opposition gradually subsided, and the economy of this brilliant illuminating medium was firmly established. What an industry it has become! It is remarkable how similar, but at a much slower rate of advance, has been the introduction of nitro-glycerin. The vested interests of the powder mills, corresponding to the coal oil factories, with their influence, through business relations, over contractors; the press prompted to chronicle accidents in sensational items, which were too terrible to need exaggeration—all tending to stigmatize the new explosive, as if it were a compound not subject to chemical and physical laws, and absolutely ignoring the fact, that man's ignorance, recklessness and cupidity, caused these accidents, which would cease so soon as the properties of nitro-

glycerin were understood, and the silly fancies passing current as "theories of explosion," replaced by views founded on observation and actual experiment—provided the incorrigible recklessness of the miner could be subjected to a reasonable observance of discipline. The first arrival of nitro-glycerin in Gotham may be thus chronicled:

The city of New York was startled one fine Sunday morning (1865) by an explosion in Greenwich Street, opposite the Wyoming Hotel. The windows of every house within one hundred yards of the entrance to the Wyoming Hotel were shattered, pedestrians were thrown down, and the pavement broken up. A few minutes previous to the explosion, one of the guests in the hotel had been engaged polishing his boots; for this purpose he had drawn from under the counter of the hotel office a small box, on which he had rested his foot; noticing a reddish vapor emanating therefrom, he drew the attention of the hotel clerk to it, who taking the box in his hands made his way to the front door and threw it into the gutter, whereupon explosion instantly followed.

An investigation of the circumstances connected with the storage of this box, developed the following facts: Some time previously a passenger from Germany who had occupied a room at the hotel, being unsuccessful in obtaining employment, had left it as security for his board, stating it was Glonoin Oil, a new material that had been used in Germany for blasting purposes with great success, that he, the passenger, had been intrusted with an agency for introducing the same to miners and others, but had failed to get it introduced into use; undoubtedly the box contained nitro-glycerin, manufactured by the Nobel Brothers, who had a manufactory where this explosive was compounded, at Hamburgh.

In the early part of the year 1866, this substance was again a prominent subject of discussion, owing to an explosion followed by the burning and ultimate destruction of the steamer "European," one of the West India mail packets, lying at the railway wharf of Colon or Aspinwall, on the Atlantic side of the isthmus of Panama. Knowing that nitro-glycerin was on board under the name of "glonvene" or "glonoin oil," on its way to the gold mining districts of the North American Pacific

states, as an explosive or blasting agent, it was concluded that the explosion was due to this substance. Unfortunately, forty-seven persons were either killed at the time of the explosion, or died shortly afterward from the injuries they sustained. Immediately succeeding this accident, another explosion occurred in the office of Wells, Fargo & Co., in San Francisco, by which eight persons lost their lives. The damages by the explosion on board the "European" were estimated at one million dollars, for the vessel, built of iron, and of unusual strength, was destroyed, and the pier, with an upper railroad track for unloading cargo, and warehouses for storing freight, were completely wrecked. The San Francisco explosion involved a further loss of a quarter million dollars.

In all the above cases, the nitro-glycerin manufactured at Hamburgh, reached New York safely; in the Wyoming Hotel explosion it had been lying in the hotel several weeks, in the San Francisco catastrophe it had been transported over the Isthmus and re-shipped by steamer as express freight by Wells, Fargo & Co., to San Francisco, and carted to their office in Montgomery Street before the explosion occurred. It subsequently transpired that the immediate cause of the explosion at Aspinwall was a case slipping from the slings whilst being hoisted out of the hold of the vessel. In San Francisco, the circumstances, as detailed to the writer, were as follows: A man passing by Wells, Fargo & Co.'s office, heard one of the employes address a gentleman riding on horseback, saying, "Doctor, we have got a case of glonoin oil, and it seems to be smoking, I wish you would step in and advise us what had better be done with it;" the doctor (Hill) dismounted, requesting a passer by to take charge of his horse and walk it up and down the block, the animal being too high spirited to stand without an attendant; scarcely had the person in charge gone a block from the office when the explosion occurred. It can only be inferred that in breaking open the case to discover the cause of leakage of red fumes, the nitro-glycerin was exploded. I have since ascertained from the New York consignee of this parcel of nitro-glycerin, (Messrs. Nobel's agent) that after the shipment to Panama, which was only a part of the consignment from Hamburgh, the agent, leaving another portion in warehouse in Tenth Street, New York, pro-

ceeded to Lake Superior in the winter season with a part of the same shipment, where, on arrival and opening the cases, he found it had been packed in bottles, surrounded with sawdust; in congealing, the contents had burst the bottles, a portion of the nitro-glycerin being found solid in the neck of the bottle. This, therefore, if correctly reported, would go to prove the Nobel nitro-glycerin expands, during congelation[1]. What had been bottles containing nitro-glycerin, were now fragments of broken glass, while the nitro-glycerin itself, owing to the extremely cold temperature of a Lake Superior winter, was found in solid mass of the exact mould of the bottle that had contained it. Upon discovering this condition of the cases and their contents, the consignee at Lake Superior telegraphed to his correspondent in New York: "Direct Messrs. Bandmann to throw the cases of nitro-glycerin, shipped to them, overboard on arrival." Probably, in the belief that the temperature of the upper lakes was the cause of the broken bottles and that the warmer temperature of the tropics and San Francisco did not apply, this advice was neglected.

Reflecting as a chemist upon these explosions, that here was a compound made at Hamburgh, carted to the wharf, loaded on board steamer by the stevedores, voyaging to London, reshipped to Panama, the express portion of it forwarded across the Isthmus by railway, thence lightered to and loaded upon the steamer, bearing twelve days' voyage to San Francisco, where on arrival it is taken to the express office, previous to being forwarded to the mines; now how did it happen, since there is no effect without a cause, after all this handling, that explosion took place? Determined to solve this problem, I undertook the preparation and qualitative examination of nitro-glycerin. Residing at that time at Titusville, in the oil region of Pennsylvania, where the disastrous results of speculations in oil territory during the previous year, compelled most of us to "masterly inactivity," I had the leisure, whilst my curiosity was piqued to discover the apparently anomalous properties which this explosive seemed to

(1) This property distinguishes it from the Mowbray tri-nitro-glycerin, the latter contracting about one-twelfth of its bulk in congealing; further, the Nobel patents claim a preparation which congeals at 55° F, whereas the Mowbray tri-nitro-glycerin congeals at 45° F. Did the patentee comprehend the properties of the compound he described, if his description be correct, no further evidence is necessary to prove an actual difference of composition between the two preparations.

possess, and, in 1866, after maturing a process patented April 7, 1868, I inserted a brief advertisement in the *Scientific American*, offering to manufacture nitro-glycerin on a large scale for miners and others.

We may regard Grove's nitric acid battery as the primary cause of the discovery of the nitro compounds. Professor N. J. Callan, of Maynooth college, Ireland, suggested the idea of adding concentrated sulphuric acid to the nitric acid of the constant battery. By this means not only was it found that the conducting power was increased, but the action maintained much longer uniform. In studying the cause of this improvement, Schonbein made a series of experiments on what is termed "the passivity" of metals, especially iron; that is, the remarkable fact that whilst iron is violently attacked and rapidly dissolved by nitric acid, or nitric and sulphuric acids, when water was added to these acids, yet, when these acids are concentrated, that is, only containing the water necessary to render them liquid, they appeared to have little or no effect upon iron. Various investigations on this subject have been communicated by W. Beeby, W. Rolleman, G. Welzlar; the latter, by the way, first described this peculiar deportment in iron as early as 1827. But in the latter part of 1845 and early in 1846, Schonbein, having formed peculiar views which he aimed to substantiate, relative to the nature of nitro-sulphuric acid, was induced to submit a number of organic substances to its action; on immersing clean cotton in nitro-sulphuric acid, it appeared to be unacted upon; it was removed from the acid, pressed and washed and placed near the hot stove of a drying chamber to be dried; on going to examine it—lo, it had disappeared! Another parcel was similarly treated and attempted to be dried over a hot stove, when suddenly it disappeared with a flash; and on repeating the experiment, but drying in a current of dry cool air, gun-cotton, as it was afterwards named, was produced.

Soon after this discovery, a violent controversy arose among chemists, one party alleging that it was physically impossible that so delicate a material as cotton fibre could change its elements, losing one atom of water and replacing it with three atoms of nitric acid, without a more obvious change of structure, and explained that it was simply the absorption of nitric

acid into the interstices of the cotton. Another party as stoutly maintained, it was a true chemical change. To use Walter Crum's language—"pure gun cotton is lignine, in which three atoms of water are replaced by three atoms of nitric acid." [1]

Ascagne Sobrero, in 1846, then a pupil in the laboratory of Pelouze, the eminent French chemist, who devoted twenty years of his life to the investigation of the chemistry of oils and fats, undertook a series of experiments in this direction, and made similar explosive preparations [2] from dextrin, mannite, cane sugar, and glycerin. Sobrero, therefore, is the discoverer of nitro-glycerin, and how this discovery was reached, the preceding details indicate.

A description of nitro-sugar was published by Lewis Thompson [3] Dec. 8, 1846, (Schonbein's patent specification for gun cotton was published April, 1847, and gun cotton was shown by him at the British Association, Sept. 1st, 1846).

L. Thompson directs:—"Mix together three parts of strong sulphuric acid and one part of strong nitric acid, place the whole in a freezing mixture for some minutes, then add, slowly, one part of finely powdered sugar, and mix the whole with a glass rod; in three or four minutes the sugar will become pasty and is then to be removed and thrown into a large quantity of cold water. After the excess of acid is removed it must be kneaded in warm water (from 90° to 100°). It must next be boiled for several minutes in a strong solution of carbonate of soda or potash, after which it may be carefully dried and fused at a heat not exceeding 235° F.; or it may be dissolved in alcohol and the solution evaporated to dryness. Although made from sugar, it is, I believe, the bitterest substance in nature. Five grains placed twelve hours in eighty gallons of water, rendered the whole intensely bitter, yet it had lost no appreciable weight."

When anhydrous (free from water) it is very inflammable, and once lighted it is difficult to extinguish. It bears some resemblance to the alkaloids, and possesses all the characteristics of resin, except in not combining with alkalies. Dissolved in

(1) Pharmaceutical transactions, London, 1847-8, p. 31.
(2) Compt. Rend. xxiv, 240.
(3) Pharmaceutical transactions, 1846-7, vol. 6, p. 349.

ether it serves as a varnish, rendering grains of gun powder covered with it impervious to water, and very explosive.

In view of the preceding matters of record, there would seem to be some audacity in the published assertion (*Troy Times*) that A. Nobel was the inventor of nitro-glycerin! The brothers, Henry and Alfred Nobel, are entitled to the credit of introducing this explosive as a blasting agent in Norway (1864), and attempting to control its use under patents in various countries; that in the United States has been surrendered, and reissued in five divisions, these five reissues again surrendered and reissued in three divisions, these three divisions again surrendered and reissued in two divisions, passing from A. Nobel, to the U. S. Blasting Oil Company, thence to the U. S. Nitro-Glycerin Company, and latterly controlled by the Giant Powder Companies; upon a very careful examination of the original patent I fail to detect Nobel's invention, and after five years' wrangling and litigation, reissuing and patenting, a chancery suit, in which I had the honor of figuring as respondent, was withdrawn in September, 1873, and the complainants decreed to pay costs of court, a severe disappointment to the adventurer and his assigns, who seem to have presumed too far on the presumed neglect of Americans to inform themselves of European discovery.

To recapitulate: The germ of the discovery of that numerous group, nitro-compounds, which includes nitro-glycerin, may be said to have started, when Professor Callan suggested the addition of concentrated sulphuric acid to the nitric acid of Grove's constant battery. Schonbein's investigations of this remarkable acid mixture, in its relations to the passivity of metals immersed therein, was rewarded by the discovery of Ozone and gun cotton; the latter he patented in 1846. Lewis Thompson described nitro-sugar; Vauquelin had prepared nitro cellulose by immersing a sheet of paper in concentrated nitric acid, washing and drying, which he found was explosive; and Ascagne Sobrero, in 1846, aroused by the controversy regarding gun cotton, instituted a series of investigations on these nitro-compounds, resulting in the production of nitro-mannite, nitro-dextrin, nitro-sugar and nitro-glycerin. Eighteen years afterwards, A. Nobel applied nitro-glycerin to blasting purposes—this was in 1864;

but owing to the successive fatal explosions which followed the use of the nitro-glycerin that his process produced, provoked legal prohibition in Germany and limited use in England, so that he now confines his trade to a mixture of nitro-glycerin with rotten stone, under the name of Dynamite, etc. Various fatal explosions under the management of Nobel's assignees in the United States, notably that at Ridgefield, N. J., daunted the company having control of the Nobel patents, and well-nigh ruined the manufacturing chemist who furnished the materials. Nor was this result to be wondered at, because dread of the explosive had kept the parties in interest at a respectful distance from the works, leaving laborers without educated supervision to do the work, and the accidents, as they occurred, were necessarily unexplained. This is greatly to be lamented, for at the commencement ample remuneration was awaiting the individual or company who would master the manufacture and use of this explosive, and prove its economy and safety to the mining public. How this has been achieved, in the rapid completion of the five miles of the Hoosac tunnel, after dragging along for ten or twelve years, I will endeavor hereafter to make clear to the reader.

CHAPTER II.

NITRO-GLYCERIN SAVES CRONSTADT FROM THE FATE OF SEVASTOPOL—GUN COTTON AT THE BRITISH ASSOCIATION—FIRST MANUFACTURED BY MESSRS. HALL, DARTFORD—ACCIDENT AT FORT VINCENNES, FRANCE—AUSTRIA'S USE AND ABANDONMENT OF GUN COTTON—BARON LENK ON GUN COTTON, HIS IMPROVEMENTS AND SANGUINE ANTICIPATIONS DISAPPOINTED—GUN COTTON ACCIDENT AT HOOSAC TUNNEL—PROF. ABEL'S METHOD OF MANUFACTURING GUN COTTON—ACCIDENT AT THE WALTHAM ABBEY WORKS WITH GUN COTTON—MAKERS OF GUN COTTON STIGMATIZE NITRO-GLYCERIN—TRADITIONS REGARDING NITRO-GLYCERIN SUPPLANTED BY FACTS—GUN COTTON EXPLOSION AT FAVERSHAM—FAILURE OF ROYAL ENGINEERS AT HYTHE, ENGLAND, WITH GUN COTTON.

SOBRERO'S discovery lay dormant for seven years, until the Crimean war between England and France allied against Russia, occasioned research into explosive inventions, both for offence and defence. Admiral Napier's commission was, to take Cronstadt, the stronghold of the Baltic; but, whether shallow water, or, as rumored at the time, Professor Jacobi had furnished his august master, the Czar, with a terrific explosive for charging torpedoes, and with these the channels to that renowned fortress were protected, I do not pretend to decide,—certain it is, the taking of Cronstadt, as hoped by the

sanguine allies, did not take place, the effort terminating in a simple blockade. I have been informed, however, that the explosive used by Jacobi was nitro-glycerin, which then presented difficulties in exploding with precision, that caused it to be regarded as of questionable value by the defenders themselves, of the Baltic; yet the terror it inspired was sufficient, with the accompanying difficulties of navigation, to save Cronstadt from the fate of Sevastopol.

Gun cotton, at its outset, was more fortunate. Heralded at the British association in 1846, in the glowing language of Sir J. Herschell:—"It might in the next generation arm mankind with the very wildest powers, by which they could tear up rocks, and almost call down lightning," the manufacture and sale of gun cotton was at once taken up by the celebrated gunpowder firm, Messrs. Hall, of Dartford, England, and received the impetus which means, business tact, and thorough organization can effect. The French government followed in its manufacture, but a fatal accident occurring at Vincennes, from the explosion of five barrels of nitro-cotton whilst being removed to a magazine, led to an investigation which interfered with its adoption. Then Baron Lenk, in Austria, devoted his talents to certain modifications of its manufacture, and some four hundred light field pieces were made, adapted especially for the use of gun cotton in its new form, to be organized as batteries in the Austrian service. In the brief space of one year, however, the use of gun cotton for artillery was abandoned by Austria, notwithstanding the outlay and high prestige of its noble advocate. I quote from the current literature of that day, an article evidently inspired by Baron Lenk. It is so full of warning to inventors, that I trust the reader will pardon the digression:

BARON LENK ON GUN COTTON.

"It is perhaps somewhat remarkable that although the composition of gunpowder was devised when chemistry was yet undeveloped, or more properly speaking did not exist, and although certain well-recognized defects in the properties of gunpowder remain unconquered, no substitute for it has yet been practically accepted, if indeed the Austrian variety of gun cotton now under notice has not to be looked upon as constituting an exception.

Before specially considering the properties and relations of gun cotton in any of its varieties, it will be well to take a passing glance at the theoretical conditions any material employed as a means of balistic power should fulfill, stating the full indications of theory in the first place, to the end that any failure of compliance with those indications may the more readily be appreciated. Balistic or projectile force is immediately referable to the function of elasticity applied in a variety of ways, and by any one of a variety of agents. Material bodies assume naturally one of three physical conditions, either that of solid, liquids, or gaseous, amongst which liquids may be regarded as totally devoid of elasticity, devoid, that is to say, to any practical extent; wherefore it follows that liquids could never be employed as the immediate balistic force. Solids and gases, however, are available, and one or the other has ever been used. A broadly-marked distinctive characteristic between ancient and modern balistic practice has next to be noted. It is this: Whereas ancient balistic engines were actuated by the function of solid elasticity, the actuating power of all modern balistic engines is gas, either compressed and allowed to expand when necessary, or developed by combustion when required. The former condition is illustrated by the air-gun, the latter by each and every variety of fire-arm, whether large or small.

Assuming the conditions of gaseous projectile force the result of combustion to be understood, but a compound from which to develop the projectile gases yet undetermined, let us now reflect upon the conditions a theorist would demand. He would, firstly, require that the explosive material should yield a competent amount of gas, the result of combustion. Other circumstances being equal, the more eligible of any two combustive materials would be the one that should yield the minimum of solid results of combustion; all which besides failing to contribute to projectile force would embarass the accurate shooting of a gun, through what is ordinarily termed "fouling." The next postulate would be that the gaseous results of combustion should be liberated with competent velocity, neither too fast nor too slow. If the former, then is the compound unmanageable; if the latter, it is incompetent. The desiderata noted having been secured, next comes the postulate that the result of combustion shall be devoid

of chemical action upon iron or bronze, the metals of which gun-barrels are constructed. Gunpowder, far from responding to all these postulates, is the material nevertheless which, better than any other, has answered the purpose of generating balistic force hitherto, with the exception of gun cotton; indeed no substitute for gunpowder having the slightest claim to acceptance by practical men has ever come before the public. There was a season during which great expectations were entertained that fulminating gold, silver, or mercury might take the place of gunpowder. Independently of other considerations, it does appear somewhat wild and unreasoned, that materials so expensive should ever have found acceptance even in imagination; the fact is, nevertheless, so. In the present condition of balistic science practical men and theorists are both agreed that, were the expense of the chemical fulminates reduced to zero, still they possess inherent defects wholly incompatible with their employment as substitutes for gunpowder. One remarkable fact in connection with these violent chemical fulminates would certainly never have been imagined—the fact, namely, that despite the violence of their explosion the total amount of gas developed by either of them is considerably less than the amount developed from any variety of gunpowder.

It is now about twenty-eight years since Schonbein, of Bale, discovered the remarkable substance gun cotton, from the application of which to projectile uses so much was expected; but anterior to the Austrian applications, presently to be noted, so little of practical uses had been achieved. It is, perhaps, almost needless to announce that Schonbein's gun cotton is a transformation effected on ordinary cotton wool, well cleansed and carded, by steeping it in a mixture of strong aquafortis and oil of vitriol. Curiously enough it so happens that whereas a mixture of weak oil of vitriol and aquafortis, or either of the weak acids separately, destroys cotton wool almost on the instant, yet if the two acids, highly concentrated, be employed, the result is not destruction of the original cotton, but its transformation almost without change of appearance, into the curiously inflammable material known as gun cotton. Whereas gunpowder, then, is a mechanical mixture of the three components, charcoal, nitre, and sulphur, gun cotton is a chemical compound. Whether

because of this gun cotton possesses an advantage over gunpowder remains to be proved. Theoretically it should seem that the mechanical mixture would possess an advantage in the following respect, namely, that the ratio of its constituents might be altered at pleasure to suit various conditions, whereas in the case of a definite chemical compound, such modification is necessarily impossible.

Very soon after the discovery of gun cotton by Schonbein, strenuous attempts were made both here and on the Continent to bring it into practice. Gun cotton seemed in many respects to possess advantages over gunpowder, but it was easy for one practically conversant with fire-arms, to predict the absolute failure of original gun cotton, which came to pass, so far as relates to the gunnery application of that substance. Considered as a substitute for gunpowder for blasting in mines and quarries, probably the advantages would have lain in favor of even the original unmodified gun cotton as first prepared by Schonbein; but unfortunately the dangers attendant on the manufacture of that substance, were such as to lead to the speedy discontinuance of certain works established here in England for its preparation. With this discontinuance, all further attempts to manufacture gun cotton on the large scale were, in these islands, abandoned. Not so on the Continent, however, especially in Austria, where the hope was never given up, that gun cotton would at some time not long distant—and certain modifications having been effected—take the place of gunpowder for many purposes of balistic projection, at least, if not for all. This result would seem to have been achieved by Baron Lenk, according to the published document now lying before us.

Prior to indicating the specialties of Lenk's gun cotton, as distinguished from the original material of Schonbein, it will be well to point out the existence of certain shortcomings as regards the latter—shortcomings which if not obviated must ever have prevented the adoption of gun cotton instead of gunpowder for fire-arms in general. Schonbein's gun cotton is eminently hygrometric; it absorbs moisture rapidly, and that moisture is never a constant quantity, varying from day to day with the hygrometric condition of the atmosphere. Being loose in texture it has not the equivalent of grains in gunpowder,

wherefore one and the same grade of combustive rapidity exists for every fire-arm, whether large or small. It suffers from dry atmospheric influences—the power naturally locked up within, and the normal resultant of which is explosion, tends to the establishment of a molecular change, analogous to decay; wherefore, time enough being given, that which *was* gun cotton is reduced to the combustive state of ordinary cotton. Its manufacture is dangerous, and owing to the loose texture of the material its use does not well comport with chambered guns. All these are proved and recognized disadvantages; and the further allegation has been made that the substance is prone to spontaneous combustion: a statement that, according to Baron Liebig—and his testimony accords with our own—has never been borne out. In the presence of these known drawbacks, little wonder that the idea of employing gun cotton for balistic purposes was speedily in this country abandoned. Some members of the Austrian service were more sanguine, Baron Lenk occupying the foremost rank. Experiments with the object in view of rendering gun cotton effective for ordinary purposes of warfare never ceased to be prosecuted in Austria, and, according to the treatise before us, the result has been eminently successful. Lenk's gun cotton and the material of Schonbein may be looked upon as identical in the preliminary stage. It is generated by steeping ordinary carded cotton in a mixture of sulphuric and nitric acids; and the chemical reaction having taken effect the result is washed assiduously with the intent of removing every lingering trace of acid, the presence of which would cause deterioration of property. Complete purification having taken effect, the cotton, now rendered explosive, is dried without heat by centrifugal machinery, and in this treatment the chief cause of manufacturing danger is avoided. The peculiarity of Baron Lenk's treatment now begins. In order to obviate all direct atmospheric influence, the explosive cotton is steeped in a solution of soluble glass, which permeates between every filament, so that when the cotton is again dried each fibre is coated with a sort of varnish. The finality of treatment consists in imparting the equivalent of grains, so that, within practical and necessary limits, any grade of velocity of combustion may be commanded. The means by which this is accomplished are no

less simple than they are injurious. Spinning is the agency brought into requisition. If the equivalent of large gunpowder grains be desired, the explosive cotton is spun into large threads; if the equivalent of small grained gunpowder be aimed at, small threads are produced by machinery. The next and final process consists in winding the spun cotton into cylindrical forms for the purpose of being used as cartridges. The only branch of all this complex process which seems theoretically dangerous is that of spinning, but it is asserted that safety may be infallibly commanded by working the spinning machinery with competent slowness. It is worthy of note that the Austrian military authorities were originally much opposed to the idea that gun cotton could ever be effectively used in place of gunpowder; and that the ministry of war (*Kriegs Ministerium*) appointed a commission of strong dissentients. Nevertheless the evidence brought before them was so conclusive that the result has been the establishment of gun cotton batteries in the Austrian service; which, according to the treatise of Baron Lenk, now under notice, have amply responded to the hope they had begotten. The following presents an abstract of the advantages possessed by gun cotton over gunpowder, as represented by the Austrian commission.

(1.) The weight of the new explosive compound required to produce equal effects either in heavy ordnance or in small guns is, to the weight of gunpowder, in the proportion of 1 to 3.

(2.) The constancy of effect of the new explosive compound is far greater than that of gunpowder, and it must be acknowledged ensures much greater precision of aim.

(3.) The new explosive compound, after having been duly preserved for more than ten years from the time of its manufacture, shows no alteration prejudicial to its effects and qualities.

(4.) The injurious effect (*einwirkung*) of ordinary gun cotton on the barrel of bronze or other guns, is entirely obviated (*ouf-gehoben*) by the use of the new explosive compound. As a proof of the above it may be stated that in the official trials of 1860, after more than 2,000 rounds fired from a bronze four-pounder in the shortest possible time, the efficiency of the gun was not in any way impaired. The new explosive compound

acts equally well with all kinds of cast iron guns; all sizes of breech-loading guns have been tried to 1,000 rounds per gun with the new compound without having sustained any damage whatever.

(5.) The method of producing the new explosive compound leads us (the commissioners) to the conclusion that the manufacture of this preparation is of a far easier and less dangerous character than that of gunpowder; and the apparatus required is simple and inexpensive. During the summer of 1861, more than fifty tons of the new explosive compound were produced without the slightest accident, though not in a suitable factory.

(6.) The manufacture of all kinds of cartridges of the new explosive compound for guns and miners is far simpler and more expeditious than that of gunpowder, on account of the exclusive employment of machinery, whereas, with gunpowder cartridges, hand labor is predominant.

(7.) The transport of the new explosive compound to the most distant parts of the empire, both by railway and common conveyance, under intentionally difficult circumstances, has always been effected without any hindrance whatever (*austandlos*).

(8.) The new explosive compound after burning leaves only an exceedingly slight residuum (*nur ausserst geringe Ruckstande*), so that the barrel of the gun, after many rounds, is scarcely blackened (*nach vielen Schussen Kaum geschwarzt*), and the disagreeable smoke attending the explosion of a gunpowder cartridge is altogether absent.

(9.) The new explosive compound, after having been sunk under water from six to eight weeks, and afterwards dried by machinery, which occupied but a few minutes, was as powerful in effect as before its submersion.

(10.) The recoil of the gun when using the new explosive compound is far less than that caused by gunpowder.

(11.) Supposing the new explosive compound to produce only the same effect as a corresponding quantity of gunpowder, there would then be no remarkable difference between the cost of the two preparations; but should the manufacture of the new compound be prosecuted on a grand scale, with suitable

machinery, it might be produced, quantity for quantity, considerably cheaper than gunpowder. It is also to be mentioned that the low specific gravity of the new compound, imposing much less expense in conveyance, together with the possibility of employing lighter guns, will be a saving not to be overlooked.

Such, then, is the statement of facts in regard to this gun cotton, as they have come before us. Possibly Baron Lenk may have written under the influence of that enthusiasm so common to inventors, and so necessary to the success of their inventions. It may be that some of the positive statements as to the superiority of gun cotton over gunpowder will have to be modified. Still it is a fact that batteries of gun cotton ordnance have been established[1] in the Austrian service, on the recommendation of a military commission, the individuals of which began their investigations under the influence of strong impressions adverse to the military employment of gun cotton."

Gun cotton was tried at the Central shaft in 1865, but an accident which cost the life of one man, and injury to three others, under conditions that were supposed to have been incapable of starting explosion, caused its abandonment. Since then the celebrated Professor Abel, of Woolwich arsenal, England, has devoted his best energies to make a success of nitro-cotton. Believing that imperfect washing, at the latter part of the process, was one principal cause of decomposition or change of its properties, Mr. Abel reduced the nitro-cotton to a pulp, and, with a view to render it suitable for sporting purposes and artillery, mixed this pulp with other untreated cotton, formed it into sheets resembling card-board, and this was and is punched into disks of suitable caliber for shot guns. This process was deemed so valuable that the patent for it, I understand, was purchased by the Messrs. Prentice of the Waltham Abbey powder works, Faversham, for $200,000. An accident at the factory, in which two sons of Messrs. Prentice were killed, by an explosion of the dry-house—the young men leading the way in full confidence they could safely remove a large quantity from a near-by building without risk of explosion, a fatal mistake—interrupted this enterprise. It was subsequently asserted, after coroner's inquest, that the materials had been tampered

(1) These batteries have since been discarded.

with, and this was suggested as the cause of the accident. Stimulated by the great loss to the Messrs. Prentice, Mr. Abel has since been indefatigable in his labors to reinstate gun cotton in public opinion, and has made some valuable suggestions, and published some useful papers on explosives, in the scientific journals. His articles on explosives, when referring to nitro-glycerin, have seemed to the writer one-sided, and chiefly devoted to the specialty of gun cotton, their language asserting nitro-glycerin to be treacherous, too dangerous to use. To such assertions I take exception, believing that six years of manufacturing, without injury to any one single man during the whole period, whilst engaged at their work, justifies a view different from that which has made nitro-glycerin a failure in England. If, however, the old mother country is content with a less powerful explosive, if the able chemist of her chief arsenal, biassed by the attraction of his patents, and a sense of obligation to the purchasers, will assume that nitro-glycerin possesses properties not belonging to it, and if foreign authors have transmitted erroneous traditions current, instead of proving from their own observations the properties this explosive does possess, the cure for this error is time, and the success of their rivals.

I must again refer to the current literature of the day, as showing that compressing gun cotton adds to the contingencies of the manufacture:—

EXPLOSION AT FAVERSHAM GUN COTTON WORKS, JANUARY, 1874.

"About eight o'clock, on Thursday morning, an explosion of five pounds of cotton gunpowder of the strongest quality, for mining purposes, occurred in the finishing mill. The force of the gases naturally burst open the wooden shed in which the machine was placed. A four-horse power engine, supplied with steam from a boiler ninety yards off in the main factory, was driving the machine in an adjoining compartment. Hickford, the man in attendance, had just fed the machine and left, so that there was a full charge in the hopper. Apparently he had gone to oil the engine when the charge detonated, and, the partition being carried away, the iron shaft and driving pulley were dragged towards him by the still running engine, and fell upon him and fractured his jaw. No other serious injury was sus-

tained by him, either external or internal, and strong hopes are felt for his recovery, although from the nature of the wound it must necessarily be slow. There was no damage whatever to the adjoining drying house, in which was a full quantity of powder being looked after by Hickford's mate, a lad of sixteen. Neither were there any splinters thrown outside the ditch surrounding the area at thirty yards from the buildings, which would have harmed any passers-by. The clue to the occurrence seems to be unintelligible; but at any rate that an accident of the worst character which appears possible under the system adopted here, should have done so little harm, and only have incidentally injured a single individual, must be a valuable and satisfactory grain of comfort to all concerned in the manufacture. The building, which is entirely of wood, was not ignited or even singed; the injured man was not in the slightest degree burnt, and had the new and strong traverse which was in course of preparation been erected between the compartments (as in a few days it would have been), there is no doubt but that Hickford would have escaped uninjured, to look at the wreck around him. The mill is split and rent to pieces, and the result is of the worst degree which could happen in these works, where every forethought has been exercised. The temperature of the drying house cannot be made to exceed 100 degrees, and the ignition of the gun cotton there by actual flame could hardly cause any explosion—only a severe conflagration. Not the slightest alarm was created amongst the work-people in the factory by the accident, but the men turned out promptly and orderly to extricate the sufferer. Neither is there anything in this accident which at all affects the commercial reputation of the explosives that are about to be manufactured here on a large scale. The machinery is not yet out of tentative trials, and this particular one was the last erected, and not off its experimental tests, having only been in use for a few days. From Messrs. Hall's great gunpowder works the manager and chemist quickly arrived to offer assistance, which happily was not needed, and the manufacture of gun cotton was proceeded with throughout the day in the usual manner and with the customary security.

On Friday, Major Majendie, inspector of gunpowder factories,

made a long and careful inquiry into the accident. He has found no reason for imputing any blame or want of care in the working of the machine, which had pressed more than 200 pounds of the same powder, and was inspected on Tuesday by the general superintendent personally, as well as by the manager and the foreman of the works. The erection of another pressing machine under such further securities for the attendant as this occurrence has shown necessary, will be proceeded with at once. The manufacture of gun cotton is being carried on as usual, the accident being abnormal, and not in any way throwing any doubt upon the principles of manufacture. The accident appears in the first place to have been caused by mechanical friction of some hard substance, as the spot of the origin of the explosion is marked on the machine. In future all such machines will have strong special arrangements for the perfect security of the attendants, and confidence is felt that similar explosions may then be dealt with without any alarm, if not, indeed, with impunity."

It would also appear from the following extract that the Royal engineers have not been very successful with gun cotton in their operations at Hythe, where an attempt to blast out one of the old Martello towers failed, gun cotton being the explosive; the electric machine (Wheatstone's dynamic exploder) also failing at the critical moment. I can better appreciate the vexation of the Royal engineer officers having charge, than the disappointment of the spectators, especially as the latter had the benefit of a concert, whereat the beauty of Hythe could console the gallant engineers on the evening of the failure:—

HYTHE, England, Dec. 16, 1873.

"An attempt to blow down the ruins of No. 10 Martello tower with gun cotton, by the Royal engineers, on Tuesday afternoon week, proved unsuccessful. The effect of a previous experiment with 150lbs. of nitrated gun cotton on the tower was to destroy the roof, which fell into the interior and split the land face and sides into six nearly equal masses, the thick sea face being also cracked. On Tuesday week, 300lbs. of gun cotton were placed in the tower; first, a central charge of 100lbs. as low down in the centre of the ruins as possible; secondly, two charges of

40lbs. each against the sea face; and, thirdly, six charges of 20lbs. each against the center of each of the remaining masses of brickwork on the inside of the tower, the whole to be connected in continuous circuit, and fired by the dynamic electric machine. The wire ran from the tower in a direct line across a field to Bell bridge (a little over three hundred yards), and a short distance along the canal bank to the machine in charge of the engineers. By the hour appointed (half-past two) a number of people had assembled on the banks of the canal and other places in the vicinity, from whence a view could be obtained to witness the experiment. The signal of readiness having been given by a bugler, and then another to fire, every one eagerly gazed on the tower, but owing to some defect in the electric machine no explosion took place. A second attempt met with a like result. After a short lapse of time, and instantly following another signal, two small explosions were heard, and little puffs of smoke arose from the top of the tower, but apparently without having much effect, as the massive sides retained their upright position. The officers, under whose superintendence the experiment was made, were the first to go to the tower, and, a ladder being raised, the party entered the ruins by an aperture on the north side. Great disappointment appeared to be felt by those assembled as spectators, at the result. It is understood that a further experiment will be conducted on quite a different principle. The tower had undergone a great shaking, the cracks in the sides had widened, and small portions of brickwork been displaced, but not to any extent."

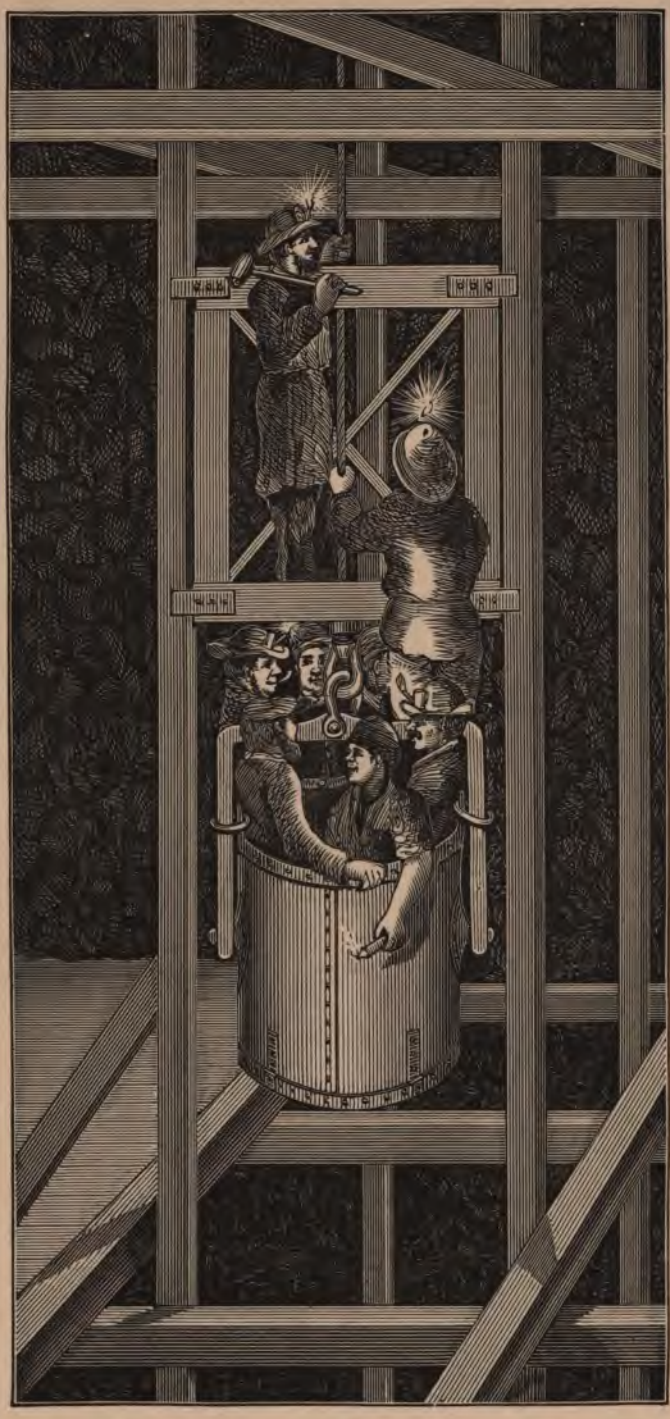
This is one of those decisive replies to the power of gun cotton that should hereafter serve as a warning to its advocates. It was to have been a crowning success for the newly patented nitrated gun cotton; the Royal engineers were entrusted with the explosion, their experience was enlisted to place the explosive where it would be most effective, and, with every precaution taken, it was demonstrated a failure, although three hundred pounds of gun cotton were consumed.

CHAPTER III.

CHIEF ENGINEER THOMAS A. DOANE'S REPORT (1866) TO COMMISSIONERS—SUPERINTENDING COMMISSIONER HON. ALVAH CROCKER'S REPORT (1867)—AUTHOR'S REPORT—ENGINEER IN CHARGE, W. P. GRANGER, TO THE COMMISSIONERS—CHIEF ENGINEER B. D. FROST'S REPORT (1868)—ACCIDENT TO J. VELSOR WHILE USING MAGAZINE FOR BATH ROOM—WATCHMAN'S NEGLECT OF DUTY AND CONSEQUENCES—W. P. GRANGER'S DISCOVERY THAT CONGEALED NITRO-GLYCERIN COULD NOT BE EXPLODED—SUBAQUEOUS BLASTING IN ERIE HARBOR, AND SUPERINTENDENT BALDWIN'S AND ENGINEER MAJOR G. CLINTON GARDNER'S REPORT—MAJOR WILSON'S REPORT—MESSRS. LEE AND DUNBAR'S REPORT—COMPARATIVE WORKING WITH NITRO-GLYCERIN AND DUALIN—SUBMARINE BLASTING ON DIMON'S REEF, NEW YORK HARBOR—NITRO-GLYCERIN TORPEDOES IN OIL WELLS.

DURING the winter of 1866-7, I received a communication from Thomas A. Doane, Esq., then chief engineer of the Hoosac tunnel, who was keenly alive to the urgent necessity of more efficient means for driving that work. I subjoin an interesting abstract of his report to the commissioners of the Troy and Greenfield railroad and Hoosac tunnel, James M. Shute, Alvah Crocker, and Charles Hudson, dated Dec. 19, 1866, referring to the work of the current year as follows:—

(Page 21.) "It has been my continual desire since entering



Miners ascending Central Shaft.

upon this work, *to learn how to fire several charges at the same time.* Last spring, in making a visit to the Bessemer steel works, in Troy, it was my good fortune to obtain an introduction to J. J. Revey, connected with the gun cotton works of London, and who was acquainted with the most approved methods of simultaneous firing. He very kindly and fully explained to me the process, and gave me a description of the electrical machine and fuses necessary. The commissioners ordered for me two electrical machines (these were the Austrian static machines, made by Ladd & Co., London), and four thousand fuses (Abel's), and several miles of conducting and connecting wire. Pending the arrival of these materials, T. P. Shaffner came with a Wheatstone magneto-electric exploder, and by it and his system of connecting wires, it was found impossible to fire more than about five charges at once, and these not simultaneously. This, of course, was far from satisfactory. Shortly after, the ebonite, or Austrian pattern, machines with the Abel fuse, ordered for me, arrived, and we very soon learned how to use them both, and have been able to fire at once as many as thirty-one charges."

How correctly Mr. Doane noted all the points to be secured, the reader will see from what follows:—

"While it is important to save the time which can be saved by this process in firing, and to reduce the risk of accident, and to avoid the smoke made by the burning of the common fuse, it is much more important to the progress, that simultaneity of firing be secured. If charges in adjoining holes can be fired as though but one charge, then they help each other, and much more rock will be torn away.

"The whole top may be thrown down, or the bottom brought up, by proper arrangement of holes, and by means of a ring of converging holes the center may be dragged out. The passage of the electric spark through one system of wires occupies, practically, no appreciable time, while through several systems it may. If the charges in adjoining holes are fired with the interval of an instant, it may just as well be a week, so far as the tearing of the rock is concerned.

"It was some time ago demonstrated by experiment, that

double progress could be made with glycerin over that with powder, at less cost. This is a wonderful achievement, and its effect upon the prospect of this work, in regard to its early completion, at reasonable cost, cannot but be good. It is true that the experiment was limited to a shorter time, by reason of the small supply of electrical fuses and nitro-glycerin, than could have been wished, and that my views may, upon further experience, be modified or changed even, but with what information I now have there is no room to doubt its fitness for our purpose. It is the testimony of all who have seen our work, including Mr. Revey, George Berkeley of London, civil engineer, Dr. Ehrhardt of London, T. P. Shaffner, and others familiar with tunneling, that while our rock is not, in general, harder to drill than many others, it is most persistently tough. That is, the number of charges we fire, if they could be in granite or lime or in any brittle stone, would bring out two or three times more of debris than now. It is therefore necessary that we should have the quickest explosive to get the best result. As preparations of mercury are not to be thought of on account of their danger, we take nitro-glycerin as being next in power, while it is comparatively safe. Whenever its extensive use shall be concluded upon, it will be necessary to secure the services of some scientific person, expert in handling it, that some antidote against headache may be discovered, and that the risk may be reduced to the lowest possible point. Bulk for bulk, which is the only useful comparison to be made here, nitro-glycerin is eight times more powerful than common powder."

In the same report, page sixty-four, the consulting engineer, Benjamin H. Latrobe, states:—

"In the east heading of the West shaft, experiments with nitro-glycerin as an explosive, were made with highly favorable results, as reported by the chief engineer, who states the forward progress in the heading proper (six by fifteen in section) as doubled, and in the heading enlargement (to ten and a half and fifteen) as trebled, by this new agent, when compared with gunpowder. He also reports $10.20 per cubic yard saved in the heading, and $3.64 in the enlargement, on a similar comparison with gunpowder, results certainly of the most encouraging character, and inviting to farther and persever-

ing effort for the safe and successful use of the new explosive."

The commissioners themselves report, page six:—

"The value and economy of nitro-glycerin as an explosive seems to have been fully demonstrated, and the method of using it with safety to the employes appears to be the only question now undetermined. Its early introduction is very desirable, and preparations are making to bring this about whenever it shall appear prudent to do so, since it is believed, on the strength of numerous experiments made in the tunnel at the West end, that by the use of this agent alone, as compared with gunpowder, the time required for completing the work may be greatly reduced."

Between the issuing of the above report and that of 1867, circumstances led to the withdrawal of Mr. Doane from the tunnel, and commissioner Hon. Alvah Crocker personally undertook the superintendence of the work. In his report, dated January, 1868, the following remarks occur:—

"Nitro-glycerin: Experiments as made in the West shaft as given by Mr. Doane, and referred to by Hon. Tappan Wentworth, chairman of the tunnel committee of that year, induced early action by the Commission. As long ago as February last I visited New York, and spent several days in endeavoring to ascertain if the article had been made there, or in the vicinity, but to no purpose. Finding subsequently that the railroads refused absolutely to transport it, the matter rested until the first of July, when I addressed George M. Mowbray, Esq., of Titusville, operative chemist, and with the permission of the Commission he was called to North Adams, and a contract concluded with him, highly advantageous to the Commonwealth. As will appear in the appendix, the public will be gratified to learn that we are giving it a fair trial."

On the fourteenth of July, 1867, the writer arrived in North Adams, and I subjoin my report to the superintending commissioner, dated January eleventh, 1868, and addressed to Hon. Alvah Crocker, superintendent of Hoosac tunnel:—

"Sir: I avail myself of permission to report progress of the arrangement to introduce nitro-glycerin for the purpose of blasting in the Hoosac tunnel, subject to the conditions imposed

by you at an interview held in the engineer's office. These conditions were :—

"First. To conduct the operations with a strict regard to the safety of the miners, and to avoid all risks that might endanger the property of the State, connected with the tunnel.

"Second. The outlay of capital for the necessary works to be defrayed at my own cost and expense.

"Third. That the nitro-glycerin should be supplied at current market rates, freight added; the State of Massachusetts furnishing a convenient site for the buildings, compressed air, and a supply of water, free of cost, and to give the subscriber a preference in consideration of his erecting the works adjacent to the tunnel.

"The reasons that led to this arrangement were, that, as the rock found in excavating the tunnel was exceedingly tough, any increased progress or lineal advance per month without any increased expenditure—in other words, diminished cost per lineal foot and quickened advance—seemed possible only by the use of a more effective explosive agent than gunpowder; that in nitro-glycerin this greater power existed, and therefore its use was desirable; the problem being convenience of supply, guarding against the possibility of accident, by planning carefully every detail in its use, rigidly enforcing every precaution, a failure in any of these points involving pecuniary loss in outlay for the works by the party undertaking its supply and superintending its use in the tunnel.

"Agreeing with you in the propriety of these views, I commenced operations. During the past two months a convenient two-story factory has been erected, and the necessary apparatus set up therein, about one thousand feet south of the West shaft; within twenty feet of this factory, a small dwelling for myself and an experienced assistant, and, about five hundred feet further south on the extreme line of land owned by the State, a magazine for storing nitro-glycerin has been constructed. Inclement weather somewhat retarded these operations; nevertheless, the crude articles used in the manufacture, and every appliance to render the labor of making a "chemically pure" nitro-glycerin, without danger to those engaged in its manufacture, were com-

East Portal, before erection of Facade.

pleted and in good working order on the thirty-first of December, 1867.

"The assistance rendered me by the gentlemen superintending the various departments of the tunnel work, materially contributed to this result, and I gratefully acknowledge their uniform courtesy and promptitude in forwarding my undertaking. Your own constant attendance at the engineer's office permitted me almost daily to submit my plans, which therefore met no delay in being subjected to the scrutiny of the engineer in charge, who as promptly reported on them.

"On the second of January, 1868, I moved up to the works, and on the following day tested the apparatus by manufacturing; and, although somewhat delayed by the necessity of drying the plastering in the magazine, and introducing suitable heating apparatus to maintain a moderate temperature during this inclement season (a neglect of which precaution remotely led to the Bergen accident), yet to-day we have a supply of nitroglycerin, properly and safely stored, ready for use. Samples of this have been duly tested for its explosive force by the engineer in charge and his assistant, giving satisfaction as to its tremendous power, and facility of explosion, with a peculiar fuse and exploder. You may therefore rely on a regular supply as needed, and I submit that a month's consumption be kept on hand, in order that it may free itself from adherent water, which, except other means be used to free it, does not separate for about ten days. Freed from this obstinately adhering moisture, it is safer and more effective for blasting purposes.

"As respects its application to blasting, during the ensuing week the conducting wires will be laid to the east heading (West shaft), and, in order to maintain the electrical machine in working order, I have arranged that the act necessary to firing a blast shall be performed in the time-keeper's office, where the air is dry and therefore favorable to exciting the charge of electricity; but the control and the means to signal for a discharge, will be in the tunnel at a safe distance from the heading. By this arrangement, although requiring more conducting wire, the incessant repairs to a costly and delicate instrument and disappointment and delay attending miss-fires will be avoided, and

the drillers will be detained from their labor at each discharge for a less period of time.

"The order of charging and firing is as follows: When the drill-holes have been completed (say every four hours), signal is made, for the cartridges which are only then taken into the tunnel (the nitro-glycerin in its containing cartridge in one vessel, the exploders, with priming and connected wires attached, in another separate vessel). On arrival at the heading, the miners are dismissed to a safe distance, the drill-holes are then gauged, to be assured they will receive the cartridges; now, and for the first time, the exploders are attached to the nitro-glycerin cartridges, and immediately passed into the drill-holes, these latter are plugged with a bung, perforated to allow the delicate connecting wires to pass (thus avoiding cutting the insulation against the rock, and confining the flame), connection is made, beginning with the return wire, to the cartridges consecutively, and on to the conducting wire. The operator now retires from the heading some three hundred feet towards the shaft, where a simple but important apparatus, or break, is arranged; he then and there connects his return wire and his conducting wire to two similar wires that lead to the electrical discharge, which duty is performed in the dry, warm room before referred to, and the explosions take place instantaneously.

"The above modification is a necessity to avoid the damaging influence of the moisture in the tunnel, so disturbing in its effect on the machine. I have only to add, that we have under-way apparatus for coating and re-covering damaged insulated wires, an improvement to insure perfect explosion of the nitro-glycerin; the manufacture of Abel's priming for fuse, the formula having been published by the inventor—matters of comparatively minor importance, but, where so many blasts are daily occurring, involving considerable saving in cost and express charges, and securing a better article when made by the individual for his own actual use, than when made simply for sale; all tending to greater safety and certainty in firing the blasts, ameliorations that have already been submitted to and approved by your engineer in charge, who will doubtless speedily report the actual results of blasting operations." Respectfully,

GEO. M. MOWBRAY, Operative Chemist.

West Portal, before erection of Facade and Retaining Walls.

The following letter from the engineer in charge to the commissioners, is interesting, as showing that the nitro-glycerin we had made was superior, and possessed far more valuable properties than that which had been imported from Hamburg:—

NORTH ADAMS, Feb. 18, 1868.

"*To the Commissioners of the Troy and Greenfield Railroad and Hoosac Tunnel:*

"GENTLEMEN:—I have to report that yesterday at four o'clock, P. M., we exploded eleven cartridges of nitro-glycerin, in charges of one-half pound each, in open holes without tamping, with entire success. This experiment was made in the east heading of the West shaft. On approaching the heading, the absence of foul gases and smoke was remarkable; the mass of broken rock lay close to the heading, and there was no appearance of any rock thrown to any distance from the heading. Inquiring of the miners if they experienced any headache, elicited the remark: they noticed a pleasant smell, but nothing further. This settles the question of its applicability in a close tunnel. I attribute this freedom from the foul gases which we noticed in our experiments a year since, to the evident purity of this nitro-glycerin; it differs greatly from all descriptions of the article, and in appearance from that we imported, being a liquid colorless as water, and free from smell or bubbles. That which we imported was a thick, yellow liquid, quite different in appearance from this. I have requested Mr. Mowbray, who manufactures the nitro-glycerin, to take charge of the blasting, and informed him that the commissioners wish him to assume the responsibility of using the nitro-glycerin until further orders, or at least until the system of firing is thoroughly organized among the employes.

"I enclose his reply, and approve his suggestions, subject to your instructions."

I am very truly yours,

W. P. GRANGER, Engineer in charge.

The commissioners for the year 1868, report as follows:

"During the summer, glycerin of a very good quality has been manufactured at this point, under the direction of Mr. Mowbray, and has been used for several months in blasting in

the tunnel east of the West shaft. No accident has attended its use. And while its effect in the heading did not meet the expectations of the commissioners, the result of its operation in the bench below the heading justifies the belief that with due provision for its economic use, and essential care and attention paid upon its management, it will prove an effective agent in the prosecution of this enterprise."

The superintending engineer, Benj. D. Frost, Esq., reports as follows:—

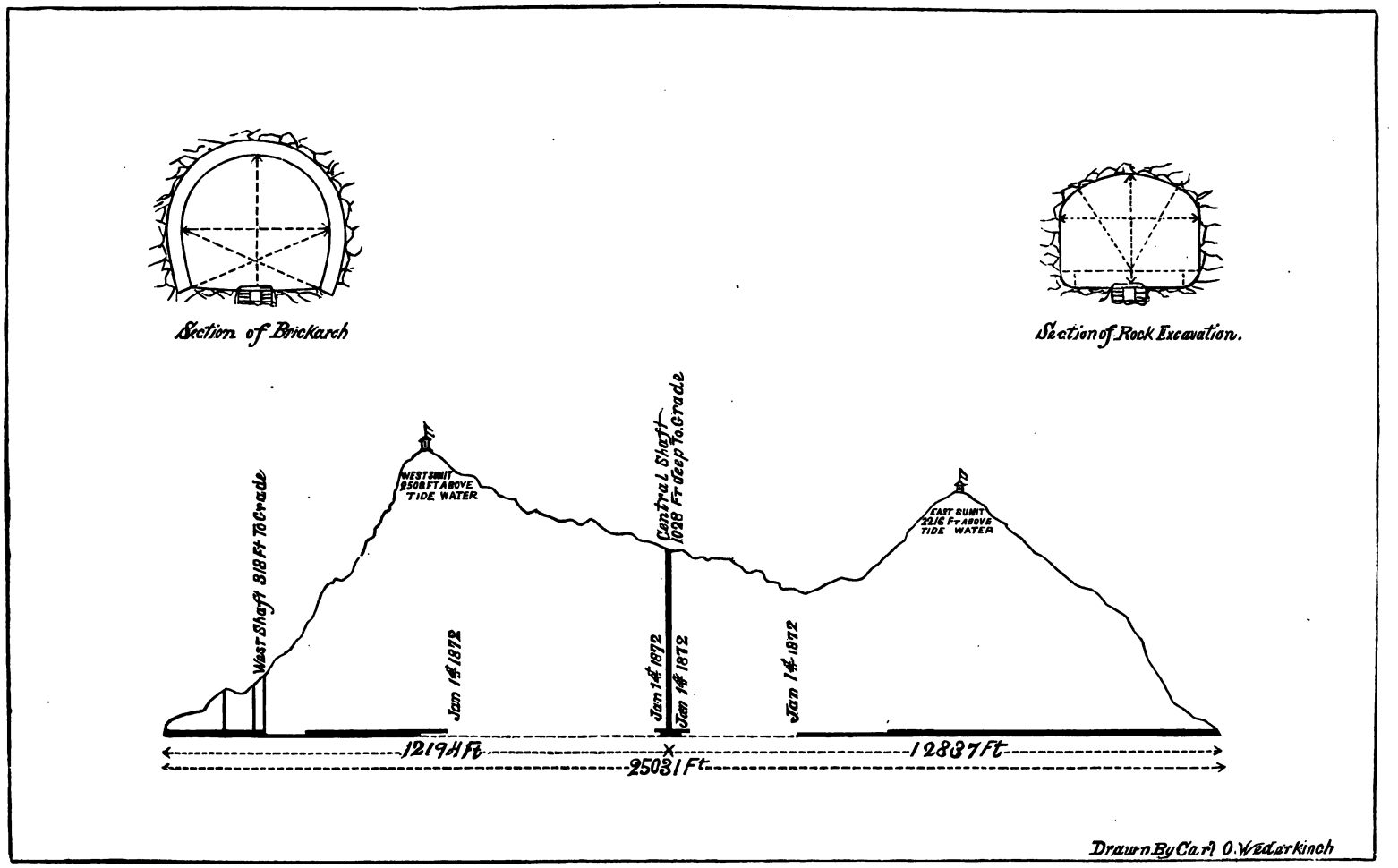
"The following is a statement of monthly progress:

		Length driven.	Total distance from W. shaft.
In November, 1867,		33 feet,	1272 feet.
December, 1867,		22 feet,	1294 feet.
January, 1868,		33 feet,	1327 feet.
February, 1868,		35 feet,	1362 feet.
March, 1868,		34 feet,	1396 feet.
April, 1868,		24 feet,	1420 feet.
May, 1868,		26 feet,	1446 feet.
June, 1868,		(1) 21 feet,	1467 feet.
July, 1868,	(Nitro-glycerin used)	47 feet,	1514 feet.
August, 1868,	"	44 feet,	1558 feet.
September, 1868,	"	(2) 51 feet,	1609 feet.

"But for the improved methods of working introduced, the advance would have been much less satisfactory than that we are enabled to exhibit above.

"Concerning the employment of nitro-glycerin and machine drilling at West shaft, it is hardly necessary to remark that many difficulties are to be encountered in the training of men to a new service, and in successfully employing a new description of fuse and explosive. Some remarks upon our experience in blasting with this compound will be found in a subsequent portion of this report. Continuous use of machine drills was commenced at the West shaft in the latter part of June, and of nitro-glycerin as an explosive in the month of August. Some delays were necessarily experienced at first, but greatly improved progress was shortly attained. Some previous trials of machine

(1) Preparing for machine drilling.
(2) September first to twenty-fourth, five-sixths of a month. Rate sixty-one feet per month.



Profile of the Hoosac Mountain, and Advance of Tunnel, January 1, 1872.

drilling has been made earlier in the present year, but without continuous progress, upon which satisfactory estimates of success might be based. The last workings made, including the month of September, up to the time of suspension, about five-sixths of a working month, attained a linear progress of fifty-one feet, with six drills only. The machinery provided at West shaft is only sufficient to supply the pneumatic power for the ordinary working of the above number, to which accordingly we have been necessarily confined.

"The two drill carriages employed are larger than those at East end, and are intended to carry five drills each—in all, ten drills working at the breast of the heading. Assuming, as we may safely, that the rate of progress is proportional to the number of drills employed, ten drills would advance one hundred feet per month; and with full power provided, and further experience to be acquired by the workmen, this, and even greater average rates of monthly progress can be made and maintained.

"These headings are run at top, i. e., above the excavations hereafter to be made, and of such height, and top outline as to correspond with the roof of the completed tunnel.

"Amounts of progress upon this section of the work during present and preceding year are exhibited in the following comparative table:—

West Shaft Section,	Heading and Adit.		Enlargement.	
	Linear Feet.	Cubic Yards.	Linear Feet.	Cubic Yards.
YEAR ENDING,				
November 1, 1867,	543	2349	161	2100
November 1, 1868,	1280	4696	82	488

"The limited employment of nitro-glycerin made previous to August first, had been directed to excavations of enlargement, which very nearly resemble open cut work. The experience of the two months, August and September, is all we have that throws direct light upon its value in mining operations, using this phrase in a more limited sense, as applied to advance of heading only. The varying hardness and tenacity of rock and other attendant conditions, make material variations in the pro-

gress of separate days or weeks, even in the same drift and with the same means and appliances of working.

"For the reasons thus stated, actual records of advance, without full knowledge and discussion of all attendant circumstances, and more especially when confined to short periods, must not be held conclusive in regard to the measure of advantage to be derived from its use. We cannot claim that, in this short time, full knowledge as to its best possible application has been obtained. Its superiority over the powder ordinarily used in blasting, as demonstrated by our experience, may be briefly expressed in the following items:—

"1. Less number of holes drilled in proportion to area for face carried forward. Estimated saving thirty-three per cent.

"2. Greater depth of holes permissible. Average depth for nitro-glycerin, forty-two inches; for blasting powder, thirty inches.

"3. More complete avail of the full depth of hole drilled. The greatly superior explosive power of the nitro-glycerin rarely fails to take out the rock to the full depth of the hole. Powder often comes short of this, and, by reason of this loss of useful effect, a large percentage of additional drilling becomes necessary.

"In all the foregoing comparison, I assume it to be understood that simultaneous blasting by electric battery is employed. The great economy of force secured thereby, whenever hard rock may be encountered, is admitted by all conversant with the matter, and, since the early part of the summer, I have continuously employed it in both the headings advancing into the mountain.

"It is hoped and expected that further experience will demonstrate an increase in each of the several items of advantage resulting from glycerin blasting; and it is only claimed that the best use was made of the short term of experiment afforded, and the most faithful and diligent effort was put forth to attain the best results and greatest benefit therefrom to the Commonwealth.

"It was a source of great disappointment that Professor Mowbray should have been unable sooner to provide a contin-

uous supply of the explosive, and, in view of the fact that a small quantity was furnished earlier in the year, it is appropriate to make mention of the obstacles which for a time delayed its further manufacture. The first lot produced was made with imported acids, reaching the actual standard of purity represented. In providing for more extended operations, acids were ordered of American works of the same expressed standard, but these, when received, were found so far below requirement, that a separate process of purification became necessary. For this process, retorts of a special pattern, not to be procured in market, had to be manufactured, and separate works erected, and in the processes, necessity for which was not foreseen, much delay was unavoidably encountered. I have been fully satisfied throughout of Professor Mowbray's earnest desire fully to meet the expectations of the commissioners and of the public, and deem it proper to make this general statement of the more important circumstances, unanticipated, and therefore beyond his control, which disappointed his purpose."

I have been thus explicit in narrating the various details connected with the introduction of nitro-glycerin at the Hoosac tunnel, in order that full justice might be done to the gentlemen whose enterprise and authority were necessary to bear up against the prejudices which the three explosions hereinbefore referred to, had caused on the public mind. It is now six years since I commenced, and have, with slight intermission, continued, to manufacture this explosive, and during this whole period but two accidents have occurred at my works. The first occurred on the twenty-third of December, 1870, to my foreman, who I surmised, in the absence of proof, in removing the clinkers from the heater, may have thrown a red hot coal on the inflammable floor boards of the magazine, moistened with nitro-glycerin spilt during three years' use, whilst adding fuel to the parlor stove which warmed it. It is a poor consolation that Mr. Velsor, the foreman, who had been engaged with me during the greater part of the past ten years, had finished his day's work and was using the magazine for a bath house, probably on account of its seclusion. Universally respected, thoroughly acquainted with the properties of nitro-glycerin, careful and untiring, cool, courageous, and without bravado, his superin-

tendence of the factory where thousands of pounds of this explosive were being handled, and in the course of distribution to different points of the United States, was steadily and quietly overcoming the dread of this powerful blasting agent; accompanying me, and aiding in the most difficult operations of submarine blasting, in every case without a shadow of accident, lead to one conclusion, that some slip of the hand, failure of a muscle, started a flame, which, in a magazine crowded with receptacles for nitro-glycerin, no human power could arrest, but which, I am satisfied, his courageous sense of duty led him to attempt, and thereby sacrificed his valuable life.

The new magazine had hardly been completed, and stored with nitro-glycerin, when, on Sunday morning, at half-past six o'clock, March twelfth, 1871, the neighborhood was startled by another explosion of sixteen hundred pounds of nitro-glycerin. The cause of this last explosion, was continuous overheating of the magazine. Work at the factory had been suspended for a week, the heating arrangement was now effected by steam, in order to avoid a possibility of actual fire, the weather for several days had been close and muggy,—some parties who had visited the magazine remarked to me afterwards, that they had noticed a hot, close air, similar to that experienced on entering the drying room of a print factory, whilst the watchman confessed he had neglected to examine the thermometer, made his fire under the boiler, and gone to bed. I had been summoned, during the previous week, to Washington, taken down with sickness and unable to return home,—the new foreman, having been closely at work without any Christmas vacation, owing to the previous accident, availed himself, with my permission, (during the suspension of work at the factory) to visit New York. Fortunately, this accident involved no damage to life or limb, whilst a very instructive lesson was taught in the following circumstance: Within twelve feet of the magazine was a shed, sixteen feet by eight, containing twelve fifty-pound cans of congealed nitro-glycerin ready for shipment. This shed was utterly destroyed, the floor blasted to splinters, the joists rent to fragments, the cans of congealed nitro-glycerin driven into the ground, the tin of which they were composed perforated, contorted, battered, and portions of tin and nitro-glycerin sliced

Twelve Cans after being Subjected to Explosion of a Magazine of Nitro-Glycerin.

off but not exploded. Now, this fact proves one of two things: Either that the tri-nitro-glycerin made by the Mowbray process, differs from the German nitro-glycerin in its properties, or the statements printed in the foreign journals, as quoted again and again, that nitro-glycerin, when congealed, is more dangerous than when in a fluid state, are erroneous.

The following incident is, to say the least, instructive: During the severe winter of 1867 and 1868, the Deerfield dam became obstructed with ice, and it was important that it should be cleared out without delay. W. P. Granger, Esq., engineer in charge, determined to attempt its removal by a blast of nitro-glycerin. In order to appreciate the following details, it must be borne in mind that the current literature of this explosive distinctly asserted that, when congealed, the slightest touch or jar was sufficient to explode nitro-glycerin. Mr. Granger desired me to prepare for him ten cartridges, and, as he had to carry them in his sleigh from the west end of the tunnel to the east end or Deerfield dam, a distance of nine miles over the mountain, he requested them to be packed in such a way that they would not be affected by the inclement weather. I therefore caused the nitro-glycerin to be warmed up to ninety degrees, warmed the cartridges, and, after charging them, packed them in a box with sawdust that had been heated to the same temperature; the box was tied to the back of the sleigh, with a buffalo robe thrown over it. In floundering across the divide where banks, road, hedge and water courses were indistinguishable beneath the drifted snow, horse, sleigh and driver were upset, the box of cartridges got loose, and were spread indiscriminately over the snow. After rectifying this mishap, picking up the various contents of the sleigh, and getting ready to start again, it occurred to Mr. Granger to examine his cartridges; his feelings may be imagined when he discovered the nitro-glycerin frozen solid. To have left them behind and proceeded to the dam, where miners, engineers and laborers were waiting to use this then much dreaded explosive, would never do; so accepting the situation, he replaced them in the case, and, laying it between his feet, proceeded on his way, thinking a heap but saying nothing. Arrived, he forthwith attached fuse, exploder, powder and some gun cotton, and inserted the cartridge in the ice. Lighting

the fuse, he retired to a proper distance, to watch the explosion. Presently a sharp crack indicated that the fuse had done its work, and, on proceeding to the hole drilled in the ice, it was found that fragments of the copper cap were imbedded in the solid cylinder of congealed nitro-glycerin, which was driven through and out of the tin cartridge into the anchor ice beneath, but not exploded. A second attempt was attended with like results. Foiled in attempting to explode the frozen nitro-glycerin, Mr. Granger thawed the contents of another cartridge, attached the fuse and exploder as before; this time the explosion was entirely successful. From that day I have never transported nitro-glycerin except in a frozen condition, and to that lesson are we indebted for the safe transmission of more than two hundred and fifty thousand pounds of this explosive, over the roughest roads of New Hampshire, Vermont, Massachusetts, New York, and the coal and oil regions of Pennsylvania, in spring wagons with our own teams.

SUBAQUEOUS BLASTING IN ERIE HARBOR.

In the winter of 1869 and 1870, I received a communication from the engineer in charge, Major G. Clinton Gardiner, formerly of the United States Boundary Line Survey, concerning the harbor improvements in Erie, Pennsylvania, under W. A. Baldwin, general superintendent of the Philadelphia and Erie railroad, with a view to blasting in the harbor of Erie, so as to furnish from fifteen to seventeen feet of water for vessels lying alongside of their wharves, instead of carrying them (the wharves) into deep water. These operations were entirely successful, and I subjoin the report of Major Gardiner to General Parke, United States Engineer Corps, written previous to dredging. The certificates of Mr. Baldwin, superintendent; F. J. Wilson, assistant engineer; Charles F. Dunbar, contractor for the dredging, follow Major Gardiner's report. These certificates, it will be observed, were given after a considerable portion of the rock had been removed by the dredging machine.

Letter from Major G. Clinton Gardiner to General John G. Parke, corps of engineers, Washington city, District of Columbia:—

Subaqueous blasting at the Long Wharf, Erie Harbor.

OFFICE OF PHILADELPHIA AND ERIE RAILROAD,
ERIE HARBOR, August 2, 1869.

"*To General John G. Parke, corps of engineers, United States Army:*

"MY DEAR GENERAL:—Some days ago, I received a letter from Mr. Geo. M. Mowbray, who is the patentee of a most valuable improvement in the manufacture of nitro-glycerin. He, being interested in having his material used in the improvements at Hell Gate, requested me to report upon the experiment in blasting at this place. Being unknown to General Newton, and having no time for a report, I take the liberty of writing to you on the subject.

"Since leaving the United States Boundary Survey, I have been employed on the Philadelphia and Erie railroad, under the direction of the assistant general superintendent, Mr. W. A. Baldwin, in the improvement of their dock at this terminus of the road. The water at the end of the main pier and for a short distance inshore, on either side of the pier, is over fourteen feet deep, shoaling back to about six feet, which we had to deepen to fourteen feet. The bottom is a smooth, hard surface of shale rock, a portion of which, when exposed to the air, disentegrates, while other parts are sufficiently hard, and are used for building purposes. It lies in strata of about eight inches to twelve inches thickness, which we drilled through and blasted during the winter, and are now dredging the rock. The process of drilling was in the primitive style, with hand drills, mostly done through the ice, and the blasting, with powder, in cartridges with small tubes reaching to the surface of the water, through which the match was conducted to the powder. Firing, however, was afterwards done by dropping a red hot nail down the tube, which was quite an improvement on the match, and gave us almost simultaneous explosions. The holes drilled were five feet apart, in rows of five feet from each other, and the largest charge of powder used was a canister two inches in diameter and forty inches long. This process having been used to some extent the season before, it was commenced again this last winter, but, the work being extended, we thought it advisable to make some improvements in the *modus operandi*. After a correspondence with different manufacturers of machine drills,

we found no one of them ready for business at once, and, before we were able to make terms, our primitive style of drilling advanced almost to completion. We sent to Mr. Mowbray, who was then in Titusville, Pennsylvania, to try his nitro-glycerin, and made an experiment in a square of a little over ten yards, where the rock to be removed was over seven feet deep. The holes were drilled a greater distance apart, but to the same depth as used for powder, (fifteen feet from surface of water). In this square we blasted about two hundred and thirty square yards of rock, using fifty pounds of nitro-glycerin in cartridges fired in rows by electricity, but without a face of rock to work from, such as we had with the powder blast. This would have taken one hundred and twenty-five pounds of powder. Upon reaching the place with the dredge, we found the rock completely crumbled, *rendering dredging as easy as that of gravel*, and to the depth of seventeen feet, while with the powder blasting we have had trouble—and in two cases had to blast again—to obtain fourteen feet of water, and even then have to lift rock measuring ten and twelve cubic feet. Nitro-glycerin is certainly far superior in its effect, and would have been much cheaper to use in this case. Gunpowder does not blast to the depth of the holes drilled, whilst nitro-glycerin tears the rock from the bottom, and here seems to have penetrated three feet beyond. The reason it was not used before, was the difficulty in procuring it. The nearest factory was at Titusville, and the local as well as state laws were such that it could not be transported, except by private conveyance, which added to its cost. That used, was carried to Corry in Mr. Mowbray's carriage, over a very rough road, and thence by special train to this place. If pure, the danger in the use of nitro-glycerin is no greater than that of powder, and the premature explosions that have proved so fatal in many instances, have, without doubt, been caused by decomposition, which was the result of imperfect manufacture. If regularly manufactured, accidents will be the result only of inexperience or the neglect of instructions from those having experience. In the manufacture, the nitrous vapors that are disengaged at the time of mixing, if not entirely expelled, will make it liable to explosion from any concussion, and, from Mr. Mowbray's experience in a number of instances

with that manufactured by himself, I should judge his nitro-glycerin to be as safe as powder in the hands of experienced persons. It is of a light yellowish color, with pungent aromatic taste, rather sweet than otherwise, and is so poisonous, that in handling, should one allow it to remain on his hands, it would produce intense headache. It does not explode from the application of flame to its surface, yet will burn, but explodes only from severe concussion, as by the explosion of detonating mixtures and fulminates.

"I write to you hoping you will communicate any information my letter may contain to General Newton, as it may serve Mr. Mowbray, who I think has made a great improvement in the manufacture of nitro-glycerin, and, as he gives it his personal attention, I have no doubt it is superior to any now used.

"I was much pleased to receive the report of the blasting in California, and, should interesting professional papers be published by the Bureau, let me beg you will remember

Your sincere friend,

G. CLINTON GARDINER."

The experiments above narrated and conducted under the supervision of Major Gardiner, were continued (on the removal of the Major to the Pennsylvania Central's works at Altoona) by F. J. Wilson, under general superintendent Wm. A. Baldwin, and the results expected were entirely fulfilled, as will be seen by the subjoined communications:—

"PHILADELPHIA AND ERIE R. R.; PENN. R. R. Co., LESSEE,
OFFICE OF THE GENERAL SUPERINTENDENT,
ERIE, Penn., May 19, 1870.

"*To Geo. M. Mowbray, North Adams, Mass.*

"DEAR SIR:—The comparative values of the two materials, gunpowder and nitro-glycerin, as to results and actual cost for blasting in the harbor at Erie, cannot be positively obtained until the dredging is finished; when this year's operations with nitro-glycerin, can be compared with that of last year done with powder. The prospects thus far are so favorable, however, I regret that the use of nitro-glycerin was not adopted last year.

"On the completion of the work I shall be pleased to furnish

you with statements of comparative results, feeling confident they will prove a more full, satisfactory and valuable endorsement of your nitro-glycerin for submarine blasting, than any theoretically-based opinion can be.

"I enclose you copy of reports of Mr. F. J. Wilson, engineer in charge of Erie harbor works, and of Mr. Dunbar, contractor for dredging, which will give you an idea of the economical results to us from the use of your nitro-glycerin."

Yours truly,

WM. A. BALDWIN, Gen'l Sup't.

ERIE, Penn., May 16, 1870.

"*To Wm. A. Baldwin, Esq., General Superintendent Pennsylvania and Erie Railroad.*

"DEAR SIR:—Below please find a statement of comparative cost of drilling and blasting where nitro-glycerin is used. The 1240 pounds of nitro-glycerin were used over an area of 26,700 square feet, with an average depth of rock of about seven and seven-tenths feet, making 11,500 cubic yards of rock measured in the bed.

Cost of drilling and blasting (using nitro-glycerin),	$5,119 67
Cost of drilling and blasting (using powder),	7,475 73
Difference of cost in favor of nitro-glycerin,	2,356 06

"The difference in favor of nitro-glycerin in dredging and in time saved is not taken into consideration in the above (see Capt. Dunbar's letter)."

Very respectfully,

F. J. WILSON, Ass't Engineer.

ERIE, Penn., May 18, 1870.

"*To Wm. A. Baldwin, Esq., General Superintendent Pennsylvania and Erie Railroad.*

"DEAR SIR:—In reply to your inquiry as to the relative difference in dredging rock blasted by nitro-glycerin and that blasted by powder, I have no hesitation in saying that I am certain we can dredge twice the number of cubic yards where it is blasted with nitro-glycerin. I think I could speak safely and say three yards to one where the rock is hard. In fact,

there are places where we could do nothing with the powder blasting, when we have no trouble with the nitro-glycerin."

Truly yours,

CHAS. F. DUNBAR, Firm of Lee & Dunbar.

RESULT.—Submarine drilling and blasting with nitro-glycerin costs forty-four and one-half cents per cubic yard. Gunpowder costs sixty-six and three-fourths cents per cubic yard. Nitro-glycerin used, one ounce and six-tenths of an ounce per cubic yard of rock removed.

DIMON'S REEF, NEW YORK HARBOR.

General Newton, United States Corps of Engineers, who has been entrusted with the expenditure of the annual appropriation for the improvements in New York harbor, having constructed a floating drilling apparatus, with steam power to capstans, four steam derricks, and direct engines to lift the drop-drills, applied to me (1870) first, to enter upon a competitive test, with nitro-glycerin as compared with dualin, and with blasting powder, into which a reel of lightning fuse was inserted to ensure more perfect and rapid combustion of the powder. These tests were conducted at Hell Gate, under the supervision of Mr. Reitheimer; Mr. H. H. Pratt, on my behalf, with nitro-glycerin, Mr. Ditmar with dualin, and Mr. Gomez, for the powder and lightning fuse blasts, who respectively directed the holes to be drilled, charged them, and fired the several charges. The results were decisive of the superiority of nitro-glycerin, over both dualin and blasting powder, even when assisted by a coil of lightning or fulminating fuse, inserted in the powder. Two points were elicited, as reported by my operator: First—the nitro-glycerin tore out more rock, invariably reaching to the bottom, and sometimes beyond the bottom of the drill-hole, whilst its explosion was so instantaneous it did not cause leakage in the roof, as with dualin. Thereupon I was invited by General Newton, to arrange operations for blasting at Dimon's reef, between the Staten Island ferry and Governor's Island. Eight holes had been drilled in a circle of twenty feet diameter, with a ninth or central hole, thus leaving an average of eight feet of rock between each drill hole. Finding that the drilled holes were

shaped like an inverted cone, owing to the omission of the reamer—that is, whilst the drill, jars, sinker bar, cable and cable clutch of the Pennsylvania oil wells, had been used, the provision for remedying the effect of the worn edges of the drill, had been overlooked, and thus a very disadvantageous form of hole, viz.: funnel shaped, was the result, necessitating the use of a cartridge, whose diameter must not exceed that of the smallest, which in this case was the lowest, part of the drilled hole; the irregularity and jagged edge of these unreamed holes, had also to be guarded against, lest the friction of any nitro-glycerin moistening the outside of the cartridge, might cause a casualty—I therefore determined, until the reamer could be used, to take two and one-fourth inch two-ply rubber hose for cartridges, a material by no means desirable, because it afforded a cushion between the rock and the blast, but it became a necessity, from the funnel shaped drill-holes, when providing against the risk of premature explosion. The holes being four and one-half inches in diameter at the upper part, and barely three inches at the bottom,—the cartridge of rubber hose, uniform throughout, containing a column of liquid nitro-glycerin, two and one-fourth inches in diameter only, and six feet long,—there was, at the upper part of the holes, an intervening cushion of water and hose, over one inch thick, and, at the lower part, a cushion of three-eighths of an inch of hose. This should have been avoided, and I have mentioned these details as a caution to future operators, who desire the full explosive force of nitro-glycerin.

The depth of water at or during high tide is about twenty-two feet, and at low tide fourteen to fifteen feet, the tide running four miles an hour, with an amount of silty matter, drainage of New York city sewerage, that renders it impossible for a diver to distinguish objects one foot from his helmet. Under these circumstances, plugs have to be inserted in the several holes, each plug attached to the other by a rope, so as to enable the diver to guide himself from one hole to the other. Owing to various interfering circumstances, the holes were only ready for blasting on the sixteenth of December, 1870; and the second day after arrival in New York, accompanied by three assistants, I proceeded to the work. There was a stiff wind blowing

from the north-west, which, meeting the tide, caused a chopping sea; the weather was cold as shown by the crust of ice attached to the scow; the frozen nitro-glycerin was thawed out by hot water obtained from the steam boiler on board the scow.

These cartridges were lowered to the diver with the connecting wire, fuse, and exploder attached, one after the other, occupying twenty minutes; two of the holes being too small to allow the cartridge to be fully inserted, these projected, one about eighteen inches, the other one foot above the surface of the holes; the diver, moreover, became entangled in the wires and, in order to extricate him, it was necessary twice to haul him to the surface, after which considerable time was occupied in moving the scow from over the site of the intended explosion, before the order could be given to fire. The amount of nitro-glycerin used to fill the nine cartridges, was one hundred and thirty-four pounds. On the order being given, the charge was successfully fired. Similar charges of nine cartridges, with more perfect holes and a heavier charge were fired three weeks afterwards.

NITRO-GLYCERIN TORPEDOES IN OIL WELLS.

The Legislature of Massachusetts having resolved to place the further construction of the Hoosac tunnel under contract, pending the transfer from State management to the present contractors, Messrs. F. Shanly & Co., I paid a visit to the oil region, and there verified the fact that nitro-glycerin, properly exploded, i. e., the charge completely exploded, was more efficient in causing an increased yield of oil, when applied to wells ceasing or diminishing their yield, than any other material. Ehrhardt's powder, Oriental powder, white powder, and ordinary blasting powder, had been used very generally, and nitro-glycerin had been alleged to have been used, but the results were unsatisfactory; as soon, however, as we started a nitro-glycerin factory at Titusville, and inserted charges varying from six pounds to fifty pounds, the results were so advantageous to the well owners, that none others would be used while nitro-glycerin could be obtained. The first explosion was in D. Crossley's well on the Weed farm, a charge of six pounds having been inserted and fired. The well, whose previous best yield had only amounted

to six barrels per day, increased forthwith to one hundred and twenty barrels of petroleum per day, and settled down to forty barrels per day, which were obtained daily for nearly a year. On the road to Enterprise, at the McKinney & Prior well, the explosion of six pounds of nitro-glycerin invariably started the well to flow at the rate of about one hundred barrels in twenty-four hours. At the Crocker wells, on the Weed farm, the increase after an explosion of nitro-glycerin was usually from ten barrels to one hundred and twenty. After a charge of nitro-glycerin in an oil well, the yield generally rises to the highest point it has ever attained, and thence gradually diminishes therefrom, apparently owing to an accumulation of paraffine, deposited in the interstices of the walls of the well. This has led to pouring down the well benzine, and pumping same out with the oil, and is another form of recuperating the yield of oil. The process of increasing the production of Petroleum in oil wells, by means of the explosion of gunpowder or its equivalent, substantially as described in the specification of E. O. L. Roberts, ante-dated May twentieth, 1866, was claimed by the patentee to cover the use of nitro-glycerin and every known or hereafter to be invented method of effecting an explosion in an oil well, and, as the case has hitherto been presented in the courts, this claim has been sustained.

As soon as the contractors commenced operations on their work at the tunnel, I resumed my manufacture of nitro-glycerin for that work, terminating my visit to the oil region, where the oil operators and producers have since been incessantly litigating the validity of the Roberts patent above referred to, with, however, up to the present date, indifferent success. The average of greatly increased production in exhausted wells, so far as my experience extended, at one hundred wells, was, that eighty per cent. were benefited, and in about twenty per cent. no marked results were obtained. When the question as to whether this form of blasting, viz: in oil wells, is patentable has been decided, it will be time to renew the careful application of nitro-glycerin in oil wells, but, at present, the careless handling, the pursuit of wealth regardless of the lives of the employed, and the unscrupulous assertion prevalent among those interested in the patent referred to, is depriving the oil producers of a

valuable agent. Since, however, the present yield of oil is ample for the consumption, this, so far as the public is concerned, is of less moment than it is to the producers, who, by the time economical and useful blasting in oil wells is needed to bring up the yield to the ever-increasing demand, will have finally disposed of this patent litigation.

CHAPTER IV.

GLYCERIN, WHENCE DERIVED—SOBRERO'S PROCESS FOR NITRO-GLYCERIN—DE VRIJ'S PROCESS—RAILTON'S, H. WATTS' AND GLADSTONE'S OBSERVATIONS—LIECKE'S PROCESSES—CAUTION TO MINERS—LEAKAGE OF CANS A SOURCE OF ACCIDENTS—W. CRUM'S METHOD OF ANALYSIS—M. L. HOTE'S METHOD—MARTIN'S METHOD—TILBERG'S ANALYSIS—PROFESSORS BARKER AND JOHNSON'S EXPERIMENT—NON-EXPLOSIVE NITRO-GLYCERIN—HOOSAC TUNNEL NITRO-GLYCERIN WORKS—THE AUTHOR'S PROCESS—GUTTA PERCHA, HOW PURIFIED—MAKING EXPLODERS.

GLYCERIN, the base of nitro-glycerin, is produced from most of the fixed oils and solid fats, by the process of saponification, that is, by treating these fatty bodies with an alkali, or other metallic oxide, in presence of water, or with water itself at a high temperature. For many years the glycerin of commerce was produced from olive oil, by boiling, in the presence of water, litharge, which yielded the well known lead plaster or diachylon, and a sweetish liquid, which, by evaporation of the water, was found to be glycerin; thus procured, however, it was apt to be contaminated with lead, and therefore very objectionable for medical purposes. The sources whence it is now procured, are the alkaline mother liquor of the soap works, when the soap is separated by common salt; also, the residue of the manufacture of stearic acid for candles, by heating

neutral fats with water or with steam (Tilghmann's process); and the action of muriatic acid on castor oil. It is apt to be contaminated with sulphuric acid, oxalic acid, lead, and more generally with uncrystallizable sugars. The demand has vastly increased of late years for medical purposes, elastic sponge, and retaining moisture in tobacco, print-works, as a preserving agent, and for floating compasses, etc., etc.

The following are the synonyms of nitro-glycerin: Nitrate of oxide of lipyl (Berzelius); glonoin, mono-nitro-glycerin, di-nitro-glycerin, tri-nitro-glycerin (Liecke)—symbol, $(C^6 H^5,)\cdot O^3$, $3NO^5$; (Hydrogen=1, Oxygen=8) the equivalent or atomic weight is 147.

Pure nitro-glycerin is nearly colorless. Usually, however, owing to coloring matter contained in the glycerin used in its manufacture, it is of a light yellow-tinted color, oily, without odor, but having an aromatic taste, Sp. Gr. 1.6 at 60° F., very insoluble in water; mixes with alcohol (one part to four parts) and ether; it separates from the alcoholic solution by the addition of water. A vinous taste is perceptible to the tongue, the maxillary glands are stimulated, and in a few minutes the individual who has tasted it from a pin's point for the first time, is conscious of a persistent throbbing headache. Slightly touching it with the hands produces a like effect. After a few days of frequent handling, the system becomes less susceptible to these effects, and workmen constantly employed in its manufacture are not affected by it. It is poisonous, a small quantity being sufficient to kill a dog (Sobrero). It decomposes at 320° F., giving out red vapors, and explodes at a higher temperature, or by concussion or percussion, crashing the containing vessel. It ignites by flame, and burns without explosion, yielding a light ethereal flame of considerable volume.

Pure nitro-glycerin may be kept for a year unchanged (De Vrij). The writer has exposed it to frost, sun and rain, for three years, and found it unchanged. Unless perfectly pure, however, it rapidly changes, becoming of an orange yellow color, evolving fumes, and seems to become a wholly differing compound, difficult, when thus changed, to congeal, except at a much lower temperature than 45° F., and is more readily exploded.

It very easily decomposes by drying in a warm room with rarefied air (Williamson).

It is instantly decomposed when dissolved in alcohol, by adding an alcoholic solution of caustic potash, the reaction being so violent as to eject the mixture from the test tube.

Nitro-glycerin in contact with the following salts: Nitrates of lime, cobalt, soda, barytes and potash; chlorides of calcium, of barium; perchloride of iron, carbonate of lime, sulphates of potash, lime and soda, was found unchanged after two years' exposure.

Incompatibles: Nitrate of silver precipitates black oxide of silver; nitrate of copper gives a precipitate of peroxide of copper, the nitro-glycerin remaining, however, bright and apparently unchanged. In a solution of nitrate of mercury, there appears a white film, a bubble of protoxide of azote, apparently adherent to the nitro-glycerin. Muriate of ammonia seems to divide the nitro-glycerin into two liquids, a light film supernatant, and the heavier liquid subjacent. The action of chloride of mercury (calomel) is but very slight. Protochloride of tin forms a precipitate of peroxide of tin, the residuary nitro-glycerin reflecting light powerfully, and as brightly as a diamond. Bichromate of potash is partly reduced to chromate. Sulphate of copper forms a very slight precipitate of oxide of copper, with apparently no change in the residuary nitro-glycerin. Sulphate of iron decomposes it, giving a voluminous precipitate, with evolution of nitrous fumes. Sulphuret of ammonia decomposes it with precipitation of sulphur. Acetate of lead, chlorine water, ferridcyanide of potassium, cyanide of potassium, sulphocyanide of potassium, and of mercury, nitroprusside of sodium decompose it, also the sulphurets of iron, and potassium.

The action of tin, iron, and lead, slowly decomposing the nitro-glycerin, especially in the presence of an acid, indicates that metals having an affinity for oxygen are the most active in promoting decomposition, evolving at the same time nitrous fumes, or protoxide of nitrogen, whilst the residuary nitro-glycerin does not seem to be affected; with sulphureted hydrogen, as with sulphuret of sodium, potassium and ammonium, the action is prompt, and, if these reagents be added in sufficient

quantity, the nitro-glycerin is wholly decomposed, sulphur being precipitated.

Ascagne Sobrero, the discoverer of nitro-glycerin, says: It may be prepared by slowly introducing syrupy glycerin into a mixture of two volumes concentrated sulphuric acid to one volume of nitric acid, Sp. Gr. 1.4, dropping it in and rapidly cooling. It seems to dissolve in this mixture without any noticeable reaction, and, by pouring it into water, the so formed nitro-glycerin separates from it. It is then washed several times in water, is next dissolved in ether, and, after evaporation, (dangerous work this) is finally purified over sulphuric acid.

De Vrij recommends dissolving 100 grammes of glycerin, Sp. Gr. 1.262 in 200 c. c. of hydrated nitric acid cooled to 14° F., taking care that the mixture never exceeds in temperature 32° F. When a homogeneous mixture has been obtained, 200 c. c. of strong sulphuric acid are added very gradually, taking especial care that the temperature of this mixture never rises above 32° F. The oily nitro-glycerin which floats on the surface is separated by a tap-funnel from the acid liquid (which yields more nitro-glycerin on being diluted with water) and is now dissolved in the smallest possible quantity of ether; this solution is shaken with water, until the water no longer reddens litmus; the ether evaporated (here take care!) and the remaining nitro-glycerin heated over the water-bath till its weight remains constant. Merck, of Darmstadt, the eminent operative chemist, found in following De Vrij's method, whilst evaporating the etherial solution, and before the temperature had reached 212°, it was accompanied by a terrible explosion. An accident from the same cause occurred in the laboratory of Dr. E. Von Gorup Besanez, and we find in "*Comptes Rendus*" an account of the effects of the explosion of only ten drops of nitro-glycerin, which, by one of the pupils of that chemist, in his laboratory, were put into a small cast-iron saucepan, and heated with a Bunsen gas flame. The effect of the explosion was that the forty-six panes of glass of the windows of the laboratory were smashed to atoms, the saucepan was hurled through a brick wall, the stout iron stand on which the vessel had been placed was partly split, partly spirally twisted, and the tube of the Bunsen burner was split and flattened outwards. Fortu-

nately, none of the three persons present in the laboratory at the time were hurt. When nitro-glycerin is caused to fall drop by drop on a thoroughly red-hot iron plate, it burns off as gunpowder would do under the same conditions; but if the iron is not red hot, but, yet hot enough to cause the nitro-glycerin to boil suddenly, an explosion takes place.

Nitro-glycerin is decomposed by evaporation, even in vacuo, over sulphuric acid at ordinary temperatures (Railton), and, when left to itself, frequently undergoes spontaneous decomposition; but, when well purified, it may be kept for a long time without alteration (H. Watts); exhibits different properties, according to the manner in which it is prepared (Gladstone).

Liecke in Dingler's *Polytechnical Journal*, prescribes the following formulæ for manufacturing the three several preparations, mono-nitro-glycerin, di-nitro-glycerin, and tri-nitro-glycerin.

Mono-nitro-glycerin: Glycerin 100 grammes.
Nitric acid, Sp. Gr. 1.3, 200 grammes.

Dissolve the glycerin in the nitric acid, and then add sulphuric acid 200 cubic centimeters.

The product should be $\left.\begin{matrix} C^6 H^5 O^2 H \\ NO^4 H \end{matrix}\right\} O^4$

Di-nitro-glycerin: Sulphuric acid containing 1 eq. water, two volumes, nitric acid, Sp. Gr. 1.4, one volume; mix the above, lower the temperature to 32° F., or below, and drop into it:

Glycerin, pure, one volume.
Prod. $\left.\begin{matrix} C^6 H^5 O^2 H \\ 2\ NO^4 \end{matrix}\right\} O^4$

Tri-nitro-glycerin: Sulphuric acid, 3.5 parts,
Nitrate of Potash, 1 part,

cooled to 0° F., produces $KO+4\ SO^3+6\ HO$; from this the concentrated fuming nitric acid is separated by decantation, and being maintained at 0° F.

Glycerin 0.8 parts is very gradually added,
producing $\left.\begin{matrix} C^6 H^5 O^2 NO^4 \\ 2\ NO^4 \end{matrix}\right\} O^4$

From the above extracts of several of the most eminent chemists of the present day, the reader will glean, that in order

to prepare this explosive, of uniform quality, invariable in composition, free from water, or any other impurity, it is not merely necessary to buy the best materials, but to have at command the means of verifying their purity before attempting its manufacture.

These points secured, viz: purity and strength of materials, i. e., glycerin free from sugar, fatty acid, saline impurities, and a mixture of sulphuric acid with nitric acid in due proportion, of due percentage of the respective acids, and not more water therein, nor in the glycerin, at one time of making, than at another; the next point to command will be, that, in combining the glycerin with the acids, when considerable heat is evolved, the heat thus evolved shall be absorbed, so that under no circumstances whatever shall the mixture exceed a certain temperature. Sobrero names 32° F.; otherwise, according to my experience, very differing nitro-glycerin will result from variation of temperature whilst mixing. Such products may be fatal to the miner, although only affecting the manufacturer in a pecuniary sense. I am led to emphasize these remarks from the fact that prospectuses have been issued to tempt contractors to buy apparatus in the one case, and offering to manufacture on the side of a railroad cutting, if required, in another case, by parties who have no experience in the manufacture, and who start in their new avocation by deriding the care, outlay and precautions that their competitors have deemed it necessary to make, in order to secure a uniform, certain, and, for mining purposes, perfectly safe explosive; for, as the product is to be handed over to the uneducated miner, who cannot estimate the risk he is subjected to, even if such a course occurred to him, it does seem to me just and proper, that the controlling engineer, the intelligent contractor, and especially the operating miner who is to handle this explosive, should be advised, that, under the term nitro-glycerin, very different substances, both as regards explosive force, and liability to spontaneous explosion, do result, unless extraordinary precautions are adopted in the selection of the crude materials, as well as securing uniformly low temperature throughout the process of making. Unless this be done, decomposition sets in, and is indicated by the emanation of fumes, by the deepening of the light lemon tint to an orange

yellow, and, at this point, the miner should decline using it, and require the manufacturer to take his place, and the risks contingent on using it.

Since many of the accidents that have occurred with nitro-glycerin, have been traced to leakage from the containing vessel, notably the San Francisco accident, probably the Panama explosion, and undoubtedly the Titusville or Enterprise explosion, besides other cases where it leaked through the bottom of the wagon and thence on to the springs, whose hammering caused an explosion; the discovery by Granger, page forty-five, confirmed by the magazine explosion, page forty-four, teach the importance of transporting this explosive in a solid state, that is, congealed. There is, however, another reason: Decomposing nitro-glycerin will not solidify at 45° F., and the consumer has a ready and convenient test for the purity of this article, by seeing to it that he invariably purchases the explosive deliverable in a solid form. Another test is, when exploded, in a close tunnel, the fumes or decomposed gases should not inconvenience the miner. Failing in either of these tests, it may fairly be rejected as an inferior article, or should be used up as speedily as possible, preferably by the manufacturer or his more experienced employes, rather than by a miner who may not be fully aware of the unnecessary risk to which he is exposed in handling impure nitro-glycerin.

METHOD OF ANALYSIS.

Walter Crum[1] describes a method of analyzing bodies containing nitric acid, applicable to the nitro-compounds; when nitrate of potash is used, it is previously purified by crystallization, and fused at little more than its melting heat; nitro-glycerin, gun cotton, etc., must be deprived of moisture:

A glass jar, eight inches long and an inch and a quarter in diameter, is filled with and inverted over mercury; a single lump of the fused nitrate, weighing about six grains, is let up through the mercury into the inverted jar, and afterwards fifty grains of water. As soon as the nitrate is dissolved, one hundred and twenty-five grains of sulphuric acid, ascertained to be free from nitric acid, are added. By the action of the mercury

(1) Pharmaceutical Transactions, vol. 7, 1848, p. 27, et seq.

upon the liberated nitric acid, deutoxide of nitrogen soon begins to be evolved, and, usually in about two hours, without the application of heat, the whole of the nitric acid is converted into that gas. Sometimes agitation is necessary, and it is easily performed by giving a jerking horizontal motion to the upper part of the jar. The surface of the sulphuric acid is then marked, and three-fourths of an inch of solution of sulphate of iron recently boiled, let up into the jar. The gas is rapidly absorbed, except a small portion at last, which must be left several hours to the action of the solution, or be well agitated in a smaller tube with a fresh portion of it. No correction of the nitric oxide has to be made for moisture, for the mixture of acid and water employed has no perceptible vapor tension.

In one experiment, 5.40 grains of nitrate of potash yielded 4.975 cubic inches of gas, at 60° F., and barometer thirty inches.

The residue not absorbed by the sulphate of iron, was 0.015 cubic inch, leaving

4.96 cubic inches of nitric oxide=1.594 grains NO^2, and which correspond to 2.869 grains nitric acid, or 53.13 of the nitrate of potash.

Four consecutive experiments yielded

53.13
53.14
53.73
53.29

Mean 53.32, or, leaving out the third experiment,
Mean 53.19

The calculated percentage of nitric acid in nitrate of potash, the acid being represented by 6.75, and the potash by 5.8992, is 53.36. Thomson gives for percentage of nitric acid in nitrate of potash 52.94, and Berzelius 53.44.

Salts in powder, which are difficult to pass through mercury without loss, may be enclosed in small glass cylinders. Nitroglycerin may be made into pellets with powdered glass, and congealed at 45°, or simply congealed, by taking great care that it is not partially thawed during manipulation.

Mr. Theron Skeel, of Albany, has furnished me with the following extract from the *Engineering Journal* of the seventeenth of November, 1871, being an explanation of M. L. Hote's method of analyzing the gases produced by the explosion of nitro-glycerin; he uses Ure's graduated electric eudiometer, made out of a green glass organic analysis tube: Introduce into the apparatus ten centimeters of the gases evolved from water by voltaic electricity, then introduce small globules of thin glass, containing from five to six milligrammes of the explosive; an electric spark being passed through the mixed gases, by means of the platina points melted in the upper part of the eudiometer, explodes the gases, breaks the small glass globules and explodes the nitro-glycerin. The gases evolved are colorless, and contain a proportion of binoxide of nitrogen. Submitted to the proper absorbents for moisture, binoxide of nitrogen and carbonic acid, there remains nitrogen. Thus:

One gramme nitro-glycerin gave at temperature 0° Cent., at 29.7 inches barometrical pressure, of these gases 284 c.c.

One hundred parts by volume contained

Carbonic acid,	45.72
Binoxide of nitrogen,	20.36
Nitrogen,	33.92
	100.00

Martin[1] has devised a method of ascertaining the percentage of nitric acid, by its conversion into ammonia. Nitric acid when mixed with sulphuric or muriatic acids, in the presence of metallic zinc, is converted into ammonia (Gmelin I, 828). By placing some zinc in a mixture of the two acids, there is no disengagement of gas, whilst the nitric acid is converted into ammonia. Hydrogen in its nascent state combines with the oxygen of the nitrogen compound, produced by the nitric acid alone.

Metallic zinc, with dilute nitric acid, gives protoxide of nitrogen; and, by taking one equivalent of this gas and four equivalents of hydrogen, water and ammonia may be formed.

$$NO+4\,H=NH^3+HO.$$

(1) Comptes Rendus, V. xxxvii, p. 947.

The nitric acid, acting gradually and slowly on the zinc, is transformed into ammonia, equivalent for equivalent. When this reaction has ceased, then follows a disengagement of hydrogen gas from the zinc, which is permitted for a few seconds. It now remains to ascertain the percentage of ammonia. The ammonia may be distilled off and then absorbed by a normal or previously ascertained quantitative solution of oxalic acid, and afterwards, to ascertain the quantity of oxalic acid not taken up, deduct this from the original quantity contained in the absorbing solution, and the result gives the percentage of oxalic acid neutralized by the absorption of the ammonia; from this the ammonia is calculated. Mohr's apparatus for the disengagement of ammonia may be used with advantage in this operation. See Mohr's *Traite d'Analyse Chimique*, supplement, p. 402, Paris, 1857.

Tilberg[1] analyzed the Stockholm nitro-glycerin with the following results: $C^6 H^5 (NO^2) O^3$ (the carbon atoms being estimated as 12, hydrogen 1, oxygen 16), and regarded it as mono-nitro-glycerin.

In proof of the fact of nitro-glycerin being explosive by concussion effected at a distance, if proof were needed, I instance that a small can, containing about four pounds of nitro-glycerin, left by the blaster about three hundred and fifty feet from the heading, and partially protected by the rail which was curved upwards to prevent the cars running over the dump, was exploded when a full charge of sixteen holes was fired in the heading at the west end of the Hoosac tunnel. It will be noted that there could be no heat developed three hundred and fifty feet from the primary explosion, and, being enclosed in an ordinary kerosene can, it appears a striking instance of the possibility of explosion from induced concussion.

Experiments of February seventeenth, 1870, by Professors Barker and S. W. Johnson, where water and glass intervened to receive the heat and concussion, confirm the fact of nitro-glycerin being explosive by concussion, without heat or pressure. In these instances neither heat nor pressure were admitted, yet the explosion blew the tub into fragments, cutting off the staves

(1) Chemical News, March, 1869, p. 151.

level with the hoops, smashing and fracturing the bottom of the tub on the rock serving as a pedestal, and sending the water up so that it descended in a shower seventy feet from the point of explosion.

It is proper I should here announce that, after a series of experiments, during my leisure hours, extending over several years, with nitro-mannite, nitro-sugar, nitro-dextrin, nitro-starch, and nitro-naphthalin, with a view to obtain a homogeneous compound convertible wholly into gaseous matter, and miscible with liquid nitro-glycerin, which would not explode under ordinary conditions, I have succeeded in obtaining such a mixture, viz :

Nitro-glycerin, thirty parts.
Nitro-toluol, ten parts.

Mixed, this will not explode when struck on an anvil, burns when thrown on the fire, and can only be exploded with very heavily charged exploders, containing, say, fifteen grains of fulminate, better and more surely, however, with twenty grains. To this I know but one drawback: it does not solidify at a moderate (45° F.) temperature, and if the containing vessel should leak, a too frequent source of accident with inferior nitro-glycerin that cannot be congealed, the nitro-toluol is liable to evaporate, and the residuary nitro-glycerin is then left with its ordinary properties unchanged, and, being liquid, liable to explosion by a hard blow between hard surfaces.

It is time that I should now accompany my reader through the

HOOSAC TUNNEL NITRO-GLYCERIN WORKS,

of whom (my readers) few have ever ventured to trust themselves within a nitro-glycerin manufactory; the very name is sufficient to make the passer-by quicken his step, till he is a safe distance beyond the dreaded precinct. Some account of such a factory will, accordingly, be interesting to many who are familiar with the article, perhaps have used it, but whose curiosity has not been of such a nature as to induce them to pay a visit to the works, where the least negligence involves a death penalty.

About one hundred yards beyond the West shaft of the Hoosac tunnel, is to be seen a board fence surrounding about

ten acres of ground, with the announcement: "*Nitro-Glycerin Works;—Dangerous;—No Visitors Admitted.*"

A drive leading between two rows of buildings brings the "visitor" to the acid house, a well-ventilated building, one hundred and fifty feet long. Here are eleven stills, each seven feet long and two feet in diameter. Under these a light, slow fire burns, which is carefully attended to, for the temperature must be kept moderate. In each of these stills is placed a charge of nitrate of soda and of sulphuric acid. A stoneware pipe conducts the gases, at a temperature of about 180° F., from each still into a stone receiver or condenser, or rather a series of four condensers connected by stoneware pipes, ranged on a platform three feet above the ground. Into three of these sulphuric acid is poured, and the fourth is empty. The nitrous vapor passes from a still to the first condenser, where a portion of it, forming, as it condenses, nitric acid, is taken up by the sulphuric acid; the remainder passes on to the second, third and fourth condensers, though a very small portion is left to pass into the last, which only requires to be emptied once a month. It takes about twenty-four hours for the still to complete the conversion of its contents into nitric acid, at the end of which time the resultant mixture of acids, about six hundred pounds, is run off into carboys, twelve of these being filled from three stills. About one hundred carboys are generally kept in stock, as the acid does not spoil when kept closed. These carboys are then emptied into a soapstone tank having a capacity of eighteen carboys, and an iron pipe, connected with the main leading from two blowers in the engine house, is inserted into the acid, causing a current of air to agitate it so as to remove the nitrous fumes, mix it thoroughly and bring it all to uniform strength. Formerly, this was effected by removing the acid into a glass vessel containing about forty gallons, and it required boiling for hours; the mode now practiced occupies only five minutes, and the risk of fracture of a glass vessel in a sand bath is avoided. The acid is then carried into the converting room, about one hundred feet long and well lighted, where it is divided amongst one hundred and sixteen stone pitchers arranged in nine wooden troughs placed in the centre and at the end of the room, and these troughs are

now filled with ice-cold water, or ice and salt, so as to rise within four inches of the top of the jar. On shelves above the troughs, are arranged glass jars, one to each stone pitcher. Into each of these glass jars, chemically pure glycerin is poured, and this, by means of a siphon, with a rubber tube attached, about two feet long, falls drop by drop into the corresponding pitcher of mixed sulphuric and nitric acids. Immediately below the shelf, in which the glycerin jar stands, is a two and one-fourth inch iron pipe, which brings a current of cold air from the receivers connected with the two blowers before mentioned. This current of air is distributed to each jar, while the acid and glycerin are mixing, by a rubber pipe, to which is attached a glass tube sixteen inches long, and with a one-fourth inch bore. During the hour and a half to two hours that the glycerin takes to run off into the pitchers, the greatest care and the closest attention is requisite. The three men whose duty it is to attend to the mixing process, have each a row of pitchers to watch, walking the whole time up and down, beside them, with thermometer in hand, and, as the nitrous fumes rise from the forming nitro-glycerin, they stir the mixture, with the glass tube before mentioned, in any pitcher that may be giving out too violent fumes. Sometimes this is caused by the glycerin running a little freely, which fires the mixture, wastes the glycerin, forming oxalic acid, and develops unpleasant vapors. In such a case, by pushing back a little wooden peg in the glass jar, the flow of glycerin is lessened, and by stirring with the glass tube the nitrous vapors dispelled. Should the engine stop working by any unforeseen circumstance, the current of air will of course be stopped, when the mixture will take fire. In this case, it is necessary to stir the mixture, and at once stop the flow of glycerin. When the glycerin and acid is all mixed, and the nitrous fumes cease to appear, the nitro-glycerin from each pitcher is dumped into a large tank of water, at a temperature of 70°, about four hundred and fifty pounds of nitro-glycerin being the amount of each batch manufactured. The nitro-glycerin sinks to the bottom and is covered by about six feet of water. Here it remains for fifteen minutes, to be subsequently washed free from any impurities. This tank projects through the floor into a basement chamber, its bottom being on a slight incline, so that

Interior of Converting Room, Nitro-Glycerin Factory.

the nitro-glycerin may run out easily. The water is first drawn off from the top of the nitro-glycerin, and then the latter is run into a wooden swinging tub, in shape somewhat like an old-fashioned butter churn, but a good deal larger in diameter. In this it is washed five times, three times with plain water, and twice with soda, a current of air working through it at the same time. The water from this tub is run off into a wooden trough, which conveys it to a barrel buried in the earth, in the side of which a hole carries it to another barrel a little lower down the hill, and this again to another barrel, whence it finds its way to the dump of rocks being removed from the tunnel; any nitro-glycerin that may have escaped in the washing process being collected and retained in one or other of these three barrels.

The nitro-glycerin is by this time thoroughly washed and ready to store in the magazine, three hundred feet distant, to which it is carried in a couple of copper pails at a time, by a man with a yoke, similar to what milkmen use for carrying their pails. Curious thought, that a man carrying a couple of harmless looking pails with only a little colorless fluid in them, should have enough explosive matter about him to annihilate a regiment.

In the magazine the nitro-glycerin is poured into "crocks," as they are called, earthen-ware jars holding sixty pounds. These crocks are then placed in a wooden tank two and one-half feet deep, which holds twenty of them, and immersed to within six inches from the top of the jars in water warmed by a small pipe from the boiler, to raise the temperature to 70°, at which temperature it is kept all the time, as nearly as possible. They remain in this water for about seventy-two hours, during which time any impurities still remaining rise to the surface as scum, and are skimmed off with a spoon. The nitro-glycerin is then chemically pure, transparent as water, refracts light powerfully, and is ready for packing. The tin cans, lined with paraffine, and containing fifty-six pounds each, are placed in a shallow wooden trough, and the nitro-glycerin, being poured from the crocks into copper cans, is again poured into the tins through a gutta-percha funnel, the bottom of the trough being covered with a thick layer of plaster of Paris, which absorbs

and renders harmless any drops of nitro-glycerin that may be spilt. The tins, when filled, are placed in a wooden trough containing iced water, or ice and salt, where the nitro-glycerin is slowly crystallized or congealed; in this condition it is stored away in small magazines three hundred feet distant, in amounts of thirty to forty cans each, until required for use.

When the nitro-glycerin is to be conveyed over the mountains, the tins are packed in open wooden boxes, with two inches of sponge at the bottom, and four rubber tubes underneath; these are long enough to allow the ends to come one inch over the top of the tin on opposite sides, thus interposing two elastic tubes between the outside of the tin and the inside of the wooden box, rendering it perfectly safe to carry. Each tin is cellular, i. e., from the top of each tin to the bottom a tube passes, about ten inches deep and one and one-half inches in diameter, for the purpose of thawing the congealed nitro-glycerin when the blaster is ready to use it, liquefaction being effected with water of 70° to 90°. The tins, being closed with a cork wrapped in bladder, are put into a sleigh or wagon, covered in summer with a layer of ice and blankets, and may thus be carried any distance in this purified crystalline state, as safely as so many tubs of butter.

The reflecting reader will note the care taken to purify the nitro-glycerin; it occupies one and one-half hours to make it, about seventy-two hours to purify, and about forty-eight hours to congeal or crystallize it. And yet there are parties who attempt to make and vend nitro-glycerin, and induce miners and contractors to use it, taken direct from the precipitating tank with all its impurities tending to decomposition, and requiring only time and moderate temperature for spontaneous explosion; hence, I believe, many accidents.

Proceeding back to the factory, two ice-houses will be noticed, capable of containing four hundred tons of ice, required for crystallizing nitro-glycerin in summer. There is a small engine-house with a boiler of fifteen horse power, and engine of about ten horse power; this latter to pump water into the washing tank, run the two "blowers," and give power in the gutta-percha factory. The air is not pumped directly into the pipe

which distributes it to the pitchers, as the pressure would not be always uniform, but into two receivers under the floor of the factory, whence it is evenly distributed, and deprived of watery vapor, which if blown into the pitchers would raise the temperature and vitiate the product.

Attached to the factory is a building about ninety feet long, for covering the copper wire (used in exploding) with gutta-percha, so as to render the insulation perfect. The first process is to purify the crude gutta-percha which is imported in blocks about a foot long. This is placed against a rasping machine with toothed knives about four inches apart, which crush and tear the gutta-percha to pieces, delivering it into a trough of water. The impurities sink, while the gutta-percha floats. It is then warmed in a steam jacketed kettle, and when still plastic is put into another tearing or rasping machine with another series of knives set closer together, from this it drops into a trough of clean water, more dirt separating. This is repeated two or three times, as it is most important that no extraneous matter should be retained in the gutta-percha, because it would interfere with perfect insulation, and so place in jeopardy the lives of several men. It is again steamed and put into a "masticator" consisting of a fluted roller working in a steam jacket; here it is "chawed up" for about six hours, until it arrives at a proper consistence; it is then passed between two smooth cylinders heated by steam, and transferred thence into a cylinder, where it is pressed through gauze wire, under a pressure of four tons to the inch. Being thoroughly cleansed, it is then steamed, masticated and pressed between the cylinders, and is ready to cover the copper wire. Five wires at a time, horizontally parallel to one another are passed through a gun metal mould with a disk at the further end, perforated with five holes, but little larger than the wires themselves, placed at the base of an upright cylinder. The gutta-percha is inserted in the top of this cylinder, and a pressure of ninety-five tons is put upon it by means of a screw, when it is pressed into slots in the mould surrounding the wires, which are then drawn from the holes in the disk, through a trough of water eighty feet long, and back again; it is then wound on drums ready for use. The "leading" wire receives

two coatings, separate dies, having larger bores, being attached to the brass cylinder.

A house is attached to the factory, for the foreman and his family.

Perfect system pervades this factory, and is absolutely necessary in the manufacture of nitro-glycerin, to ensure safety.

The steadiest men possible are selected for the work; three are employed in the acid house, working in three shifts of eight hours each, but they do not actually work more than seven hours; every movement is like clock work, every man has his place and special duty, which he is expected to perform at the proper time. In the morning, at seven or seven and a half, two men dump the carboys of acid into the soapstone tank and mix them, while a third is filling the glass jars with glycerin. This operation takes about an hour. One draws the acid, another weighs it, and a third carries it to the troughs. After an interval, during which the acids cool, three men attend closely to the converting of glycerin into tri-nitro-glycerin, knowing that their safety, and the safety of every man on the works, depends on themselves alone, during the process. After the nitro-glycerin is dumped into the water tank, two men are employed in washing it, down stairs, while two wash the stone pitchers with water; more water, temperature about 60°, is swilled on the floors so as to keep them scrupulously clean and perfectly free from atoms of nitro-glycerin, which, stepped upon while the men are at work, might send them to eternity, and the building to smithereens. The room is then prepared for next day's operations, and, by about one or two o'clock, after six, or at most seven hours' work, the day's work is done. Mr. Wilson, in charge of the magazine, has now been over six years at this work.

Making exploders is a distinct operation, requiring great precision. The materials of which the priming for fuses is composed are prepared in my private laboratory, and consist of sulphide and phosphide of copper with chlorate of potash. Considerable nicety of manipulation is required to prepare the former of these compounds so as to obtain homogeneous, uniform sulphides and phosphides, and, from the failure of several

chemists—and some of our best have attempted the preparation without succeeding, I attach great importance to this work, invariably making them myself. For, if prepared with the above ingredients, no accident can occur from atmospheric electricity, friction, etc., a contingency to which other primings now in use seem liable. The priming is then taken to the warehouse, where from three to four hands are employed in making it up into exploders. Two insulated wires, from four to twelve feet long, are inserted in a moulded gutta-percha plug, three-fourths of an inch long and one-eighth of an inch in diameter at one end, and three-sixteenths of an inch at the other, to which they are fastened by a weld of gutta-percha. Immediately before the priming is inserted, an electric spark is passed through and between the wires where the priming is put, so as to ascertain that the insulation is perfect, and to guard against the possibility of a miss-fire. This being proved, the priming is put in, and a small paper plug boiled in paraffine inserted; then a copper cap, three-fourths of an inch long and three eighths of an inch in diameter, receives twenty grains of fulminate of mercury, on the top of which a varnish is poured which prevents any of the fulminate from being shaken out by accident, or affected by vibration. This copper cap having been previously covered with a gutta-percha envelope, the electric fuse is inserted about one-fourth of an inch, when it is cemented tight, the parts painted with asphaltum varnish around the joints, and the exploder is complete and ready for service.

The "over-sensitive," so-called, primings have had for their base, I believe, fulminate of copper, discovered by Dr. E. Davy, who described three modifications,—the first white, the second brown, and the third green. (Vide Berzelius' *Chimie*, Brussels edition, 1838, vol. ii, p.p. 154, 155). Subsequently, Jabez B. Dowse of Lockport, Illinois, patented a form of this salt, which he termed "'copper amalgam,' made by digesting, at 212° F., precipitated copper, three parts; fulminate mercury, one part; water, about thirty per cent. When it contains about fifteen per cent. of water, charge the igniters."

The patentee adds: "The manufacture of 'copper amalgam' requires the utmost caution. I advise no person to attempt it

unless he is accustomed to handle the fulminates. The danger lies in the mixing when it contains grit."

Neglect of this caution—for "fools rush in where angels fear to tread"—has cost several lives, deprived one man of sight, and mutilated several; whilst merely packing into a rubber bag fired one hundred and seventy out of two hundred exploders; this happened an instant after the manufacturer, on being asked whether there was not danger in handling them, assured his inquirer who was to have used them, "Not the slightest." Both the manufacturer and his questioner were confined to their rooms for weeks, suffering from the explosion.

Various frivolous devices have been patented, not that they were really deemed worthy of a patent, but as a protection against competitors. Some of these are for the wooden plug that receives the insulated wires, one for a thread to hold the two wires together until used, another for a modification of the Austrian ebonite electric machine, etc., etc., etc. A reference to the appendix will furnish the numbers, names and dates of these patents, together with various patents referring to explosives that may interest the reader. Amongst these will be found one for a priming by the author, which consisted in substituting silver, as being a better conductor, for the copper sulphide and phosphide of the Abel composition, viz.: No. 96,465, November 2d, 1869: Phosphorous, five parts; sulphur, fifteen parts; silver, one hundred parts; mercury, twenty-five parts; chlorate potash, thirty parts.

Another, No. 128,241, June 25, 1872, consisting of mercuric sulphide, three parts; chlorate potash, one part.

Other priming compounds might be described; indeed, they may be varied *ad infinitum.* The important points to secure, are: Uniformity of composition; that they shall not offer too great resistance to the spark; that they shall not be so sensitive as to explode, either from the ambient electricity of the atmosphere, or from the electricity pervading a tunnel, caused by the friction of the air from the compressors when it escapes through the vulcanized rubber of the connecting pipe. This source of electricity, I believe, caused an accident, March, 1873, killing David Witto, followed by another, similar in every respect, a

fortnight afterwards; for, as John Smith, the blaster charging the holes on the last occasion, observed: "The moment I touched the bare wire (after the insulated portion had passed through my hand), premature explosion ensued." It had been the custom, after withdrawing the drilling machines, to allow a pretty free discharge of compressed air for ventilation; and, assuming a man in his rubber boots to be an insulated jar, the hands, face, etc., would serve as collecting points, whilst the electricity developed by the moist vesicles of the cold, expanding air, rushing through a pipe from a reservoir charged up to fifty or sixty pounds per inch, would closely resemble the hydro-electric machine and develop considerable electricity. The blaster, not aware that he is a walking charge of electricity, proceeds to his work, inserting cartridge after cartridge of nitro-glycerin, until he comes to the last, which is armed with the electric fuse. The moment his hand touches one of the naked wires, the current passes through the priming and explosion follows.

Let a blaster, before he handles these wires, invariably grasp some metal in moistened contact with the earth, or place both hands against the moist walls of the tunnel. Before taking the leading wires to the electric fuse wires, let the bare ends of the leading and return wires be brought first into contact with themselves, and then into contact with the moist surface of the tunnel or some metal in good connection with the ground, and, before inserting the armed cartridge, let him unite both of the uncovered naked wires, and touch them to a metal surface having good ground connection. Above all, do not ventilate, by allowing a free blast of air through a rubber connecting pipe, *until after the electric connections have been made and the blast fired.*

Having thus given a full account of the manufacture of nitro-glycerin and its appurtenances, I will conclude this chapter with the remark that there is no danger in the manufacture when due precaution is used; but, to paraphrase the language of Professor Tyndall, in his preface to "Hours of Exercise in the Alps": "For rashness, ignorance, or carelessness, nitro-glycerin leaves no margin; and to rashness, ignorance, or carelessness, three-fourths of the catastrophes which shock us are to be traced."

CHAPTER V.

EXPLOSIVE MIXTURES—A GROWL AT THE PATENT LAWS—DYNAMITE, OR GIANT POWDER—PORIFERA NITROLEUM—LITHOFRACTEUR, OR REND-ROCK—DUALIN—THE "NEW EXPLOSIVE COMPOUND" FURORE—MIXTURES OF NITRO-GLYCERIN WITH ABSORBENT AND NON-ABSORBENT MATTER—MICA BLASTING POWDER SUPPLANTING GIANT POWDER—SUMMARY OF SIX YEARS' EXPERIENCE.

THE laws of nature are immutable. To-day, to-morrow, forever, unchanged, unchangeable, as the great Creator himself, who established them; and it is only from scientific research, starting with the conviction that these laws are God's laws, and therefore immutable, that results of general utility can be obtained. Believing that everything which, in common parlance, is termed "an accident," is simply a violation of these laws through carelessness or ignorance, it is the duty of the scientific chemist to investigate the cause and effects of the adherence to or violation of these laws in regard to the science of which he is a student. As a chemist, I have, accordingly, applied myself to a close examination of the phenomena attending the preparation and use of nitro-glycerin, and consequently to the investigation of the mixtures purporting to be substitutes both for nitro-glycerin and for gunpowder, and of which nitro-glycerin is the active base.

And this brings before me, in all their glaring defects, the anomalies of the patent system of our country, especially in regard to chemical compounds. For the past hundred years, the greatest chemists the world has known, have given the results of their researches free, and untrammeled by any patents, though they might, indeed, have justly taken toll of the world at large for their discoveries. I need only instance Berzelius, who threw open to the world the numerous discoveries of his long and valuable life, and Pelouze, the celebrated French chemist, who devoted thirty years of his life to the investigation of the constituents of fatty matters and their decomposition into stearic, margaric, oleic acids and glycerin. Let the reader picture to himself, for a moment, what would have been the state of affairs in the manufacturing world, had all the chemists of the last fifty years patented every discovery they made, every mode of preparation they suggested; how dark, gloomy and uncertain would the path of our manufacturers have been; they must almost have stood still until these patents, and perhaps their renewals also, had expired. By such a course, the bleaching and printing of cottons, and all the numerous processes dependent on applied chemistry, would have been deferred half a century; for it is only by the quick, free application of the discoveries of the unselfish chemist, that the progress that has been made was possible. What a contrast to the self-aggrandizement of the present race of patent-seeking chemists! An individual, with the labors of the grand army of scientific chemists for the past hundred years before him, selects one, two or three chemical compounds, mixes them, modifies to a certain extent some property of either of them, applies for, and obtains, a patent. Then for seventeen years this "ghoul" sits over his mixture, and, with the assistance of a lawyer, proceeds to blackmail any one, who, in attaining certain results, is led by the properties of the several compounds to avail himself of a similar mixture. The discovery of a Sobrero is attempted to be appropriated by a Nobel and his assignees, and, with the confidence inspired by the weakness of a patent examiner, who chuckles at the delusion of the patentee, they absolutely infer that, because they have a patent, they can appropriate the result of the chemist's labors obtained twenty years before. The

patent office secures thirty-five dollars, the examiner his salary[1], and the ceilings of the noble building at Washington are ultramarined, until the visitor's eyes are dazzled with the brilliant color. Finally comes a suit in chancery, in which thousands of dollars are expended, and in which these stealers of other men's brains, count less on their claim than on the hope that they may so interfere with their opponent's occupation, and so deplete his pocket with law-costs, that he will submit to accept a free license, at least, and thus enable them to terrify others into payment.

The above remarks are somewhat of a digression from the subject of this chapter, but, I think most of my readers will admit that they are by no means uncalled for. I have been told, and the newspapers teem with assertions, that these patented explosive compounds, with high-sounding names, will bear "tamping" as hard as gunpowder, are safer, more powerful and cheaper than nitro-glycerin. We are a people—Barnum says—who like to be humbugged; I am afraid we are not the only people who like to be humbugged, it is a weakness of humanity, but this I do believe: the man who is addicted to humbug, had better give nitro-glycerin a wide berth; that is, if he hopes to end his days on a feather bed.

Let us briefly examine these patents—the Lord deliver us from all such—for explosive mixtures, and see the amount of invention required.

For a mixture of nitro-glycerin with rotten-stone, a patent was granted, and (the name being the only real invention) it was called "dynamite."[2]

Make a mixture of nitro-glycerin and sponge, and patent it, and forthwith "porifera nitroleum," is presented to an admiring public.[3]

(1) One examiner in the Patent Office shows as a creditor of Jay Cooke & Co., for $10.000. Let us hope, the result of his *savings* off a salary of $2,500 per annum!

(2) "Dynamite"—Patent No. 78,317, dated May 26, 1868, granted to Alfred Nobel of Hamburg, Germany, assignor to Julius Bandmann, of San Francisco, California. The following is the substance of the claim: "My invention consists in combining with nitro-glycerin a substance which possesses a very great absorbent capacity, and which at the same time is free from any quality which will decompose, destroy, or injure the nitro-glycerin, or its explosiveness. The substance which most fully meets the requirements above mentioned, so far as I know, is a certain kind of silicious earth, known under the various names of silicious marl, tripoli, rotten-stone, etc."

(3) "Porifera nitroleum"—Patent No. 93,753, dated Aug. 17, 1869, granted to Taliaferro P. Shaffner, of Louisville, Kentucky. The claim is as follows: "I claim a compound composed of a mixture of nitro-glycerin with sponge or other vegetable fibre."

Add plaster of Paris to nitro-glycerin, patent it, and you have, in all its explosive power, "selenitic powder."[1]

Try red lead and nitro-glycerin together, and, when patented, "metalline nitroleum" is the last new sensation to astonish the weak nerves of contractors.[2]

Take some gunpowder in a fine state of division, and moisten it with nitro-glycerin until it becomes "the color of mud and about the consistency of putty"; assure the editor of the Barnumtown *Inquirer*, that it has five times the explosive power of nitro-glycerin, and forthwith a flaming article appears, upon the new explosive agent, "lithofracteur," or "rend-rock."[3]

Make a compound of sawdust and nitro-glycerin, and let your patent prove that you are unacquainted with the commonest properties of sulphuric acid and charcoal, that, on the face of it, your preparation cannot possibly be made as you describe (that is not the business of the examiner, or if it be, he is so bothered by Prussian officers that these facts escape his notice), on payment of thirty-five dollars, a patent will issue, give it a name, say, "Dualin," boldly assert that its properties are unequaled; let a governor of a state, whose experience is confined to firecrackers, witness an explosion (it is not material what substance you explode before him), hire a steamer, give a splendid collation, invite all the reporters within reach, make any statements you please to them (they will be swallowed along with the collation, especially if washed down with plenty of Heidsick), and there is no telling where this halo of a patent may not carry the unscrupulous patentee.[4]

But these assertions involve loss of life; as, for instance, when Joseph Butloe was killed at the Hoosac tunnel, attempting to

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(1) "Selenitic powder"—Patent No. 93,752, dated Aug. 17, 1869, granted to Taliaferro P. Shaffner, of Louisville, Kentucky. The claim is as follows: "I claim the combining of nitroleum or nitro-glycerin with plaster of Paris, or equivalent substances, in such manner as will make an explosive compound."

(2) "Metalline nitroleum"—Patent No. 93,754, dated Aug. 17, 1869, granted to Taliaferro P. Shaffner, of Louisville, Kentucky. Claim as follows: "I claim a compound composed of a mixture of nitro-glycerin with metallic powder or atoms, however formed or produced."

(3) "Lithofracteur"—For a wonder this has not been patented.

(4) "Dualin"—Patent No. 98,854, dated January 18, 1870, granted to Carl Dittmar, of Charlottenberg, Prussia. Claim as follows: "I claim a compound consisting of cellulose, nitro-cellulose, nitro-starch, nitro-mannite and nitro-glycerin, mixed in different combinations, depending on the degree of strength which it is desired the powder should possess in adapting its use to various purposes."

introduce a dualin cartridge into a drill-hole, and, as it did not reach the bottom of the hole, endeavoring to push it in further with a "tamping-stick," a method which the inventor of dualin advocated, and asserted to be perfectly safe. Unfortunately, however, in the present case it was not so, the explosion following the first "tamp," instantly killing the operator and exploding the misstatements of the patentee.

Truly, these gentlemen are wonderful mathematicians; they have discovered that a part is greater than the whole, that various mixtures of inert matter with nitro-glycerin, have greater explosive power than nitro-glycerin *per se*.

As dualin is one of these compounds that has been brought into competition with nitro-glycerin, in the Eastern states, a synopsis of the results may possess interest. Some six different parcels of dualin in all, have been experimented with at the Hoosac tunnel, and of these the first shipment, being useless at the West end, was forwarded to the Central shaft, and there again tried; but the effects, as compared with the nitro-glycerin supplied by the writer, were not such as to justify the contractors in continuing its use, consequently it was thrown out. Another parcel, intended to be stronger, shipped in the hot summer of 1870, exploded in the cars in transit at Worcester, proving, what had been suspected from a perusal of the dualin patents, that the inventor was really ignorant of the properties of the materials of which his combination was composed. From evidence adduced at Worcester, given by the compounder of dualin, and also by a manufacturer of exploders, some of whose wares were in the same car, it appeared that the nitro-glycerin exuding from the mixture of sawdust (forty per cent.) and nitro-glycerin (sixty per cent.) of which the dualin, made at that time by Mr. Dittmar, was composed, flowed in a pool on the floor of the car; and, when the cars were set in motion, a series of sharp detonations ensued, probably from this pool of nitro-glycerin running on to the wheels and being compressed or hammered during the revolution of the car wheels on the rails, firing the pool, which in turn fired the whole shipment of dualin, together with the exploders.

After some months, further shipments were made, and in all cases the trials made by these were superintended by the intro-

Central Shaft Works.

ducer of dualin, and, in every case but one, were reported failures and rejected. In the case in which a success was reported, a small parcel only was brought along, and exploded side by side with nitro-glycerin; that is, four holes were charged with dualin, and four other holes nearly parallel with them were charged with nitro-glycerin. The enlargement was brought down, but whether the work was principally done with nitro-glycerin, and only partially by the dualin, was left to conjecture. The foreman of the drillers asserted that the side charged with dualin was seamy, whilst the side containing the nitro-glycerin was solid, and without any seam. However, it was claimed by the inventor that dualin was now a success, and a further trial (the sixth) was undertaken, and fifteen hundred pounds of dualin brought on the ground, about the twenty-sixth of November, 1870. On Tuesday, the twenty-eighth, the experiments under the supervision of Mr. Dittmar commenced, and were continued on the twenty-ninth and thirtieth; but they demonstrated beyond cavil, there being no nitro-glycerin fired at the same time to assist them, that dualin was of "no account," not one single hole having been "bottomed;" and again the dualin left over from this experiment, thirteen hundred pounds, was thrown out, as utterly unable to effect the blasting results obtained by the nitro-glycerin it was brought to supersede. Four hundred pounds of this were ordered to the Central shaft, but, the results at the East end being so conclusive, it was consigned, like all the previous shipments, to the tomb of the Capulets, and was subsequently used up for trimming, in lieu of powder.

In a previous chapter I gave a full account of the experiments made at Hallett's Point, New York. On that occasion, General Newton, of the United States engineers, reported to me that he considered that nitro-glycerin, in point of economy and power, had the advantage over both dualin and powder even when supplemented by fulminating fuse. The advantages claimed (only by the inventor) for dualin, are, that it is cheaper, safer, and more powerful than nitro-glycerin, and some experiments made in Prussia, are adduced in proof. I have to observe, on this point, that the nitro-glycerin made by the Nobel process, probably used in Prussia, I believe to be very inferior to the tri-nitro-glycerin made by my process, both in stability and in

explosive force, and it is much more readily exploded, fifteen grains of fulminate of mercury being necessary to ensure explosion of this latter, without chance of failure. Nobel's nitro-glycerin is said to expand when solid, in which state the slightest friction is said to explode it, while Mowbray's tri-nitro-glycerin actually contracts about one-tenth in bulk when solidifying, and cannot be exploded when in the solid state, except by a heavy charge of fluid nitro-glycerin fired with it. Nobel's preparation is yellow, and gives off nitrous fumes, and is claimed by the patentee to solidify at 50° F.,[1] while Mowbray's is colorless as water and solidifies at 45° F.

It may be possible, but not probable, therefore, that Nobel's nitro-glycerin is inferior to Dittmar's dualin, as used in Prussia; the latter then said to have been a preparation of nitrate of ammonia, sawdust immersed in sulpho-nitric acid, and nitro-glycerin; but that forty per cent. of washed sawdust (not treated with sulpho-nitric acid), moistened with sixty per cent. of a dark colored and evidently impure nitro-glycerin, and such was Dittmar's dualin analyzed by me, should surpass, in blasting, a chemically pure nitro-glycerin, is to expect sixty cents of currency to have more value than one hundred cents of gold, or that a part is greater than the whole. This is inflation with a vengeance.

As I have above referred to my analysis of Mr. Dittmar's dualin, I will give in full the process and result of the same, for the benefit of the reader.

Twenty (20) grammes of dualin were allowed to digest in a glass tube for several days, covered with washed sulphuric ether. The ether was then drawn off, and the residue in the glass tube washed with ether until the cessation of the peculiar persistent taste of nitro-glycerin, causing the "glycerin headache," proved that the nitro-glycerin was exhausted. The residual woody fibre was now dried thoroughly, and weighed eight grammes. A portion of it thrown on a red-hot plate did not deflagrate; this indicated it had not been treated with nitric acid, and had not been converted into nitro-cellulose. Washed in distilled water, and the washings evaporated, no saline or crystalline salt was

(1) See patent No. 50,617, dated Oct. 24, 1865,

obtained. The residue, dried and thrown on a red-hot plate, charred and burnt like any other sawdust. Now, I assert positively, the dualin I analyzed, furnished by Mr. Dittmar himself for blasting in the tunnel, was simply a compound of washed sawdust and nitro-glycerin (actually yellow fuming nitro-glycerin).

I have deemed it due to myself to extend these observations further than I intended; but, in the interest of truth, I could not permit the friendly notices of the press, which have been industriously secured, nor the biased views of men employed in exploding (to whom payment of ten dollars was promised, for every case of dualin used, to exaggerate results), to mislead mining contractors, and I stand prepared to prove that one hundred parts dualin are only equal to fifty parts pure nitro-glycerin, for practical blasting purposes. Dualin is a mixture varying according to the humor of the compounder, but I have never found it exceeding one-half the strength of tri-nitro-glycerin; it has all the danger of the Nobel nitro-glycerin, with the additional tendency to decomposition sworn to by Mr. Dittmar himself at the Worcester investigation, owing to its being an admixture of organic matter with nitro-glycerin, and its inventor (as evidenced by his patent, where he proposes to concentrate sulphuric acid, and free it from nitrogen, by boiling it with charcoal!), does not understand the properties of the commonest commercial compounds he undertakes to handle. These facts determine, I submit, the superior advantage of a uniform chemical product, produced under invariable conditions, especially since it is more difficult to explode and is proportionately safer, and, above all, has double the effective force.

Mr. Dittmar's promises have failed, and his representations have been disproved by the results at the Hoosac tunnel. Up to October, 1870, he had six trials, of which he only claims one as a success, though he did succeed in inducing the employes to misrepresent the facts to the contractors, and thereby obtained a testimonial; but over two thousand pounds of his dualin were buried in the Berkshire mountains—a stern pecuniary lesson, verifying the truth of the old Roman apothegm, so much neglected in modern times—"*Magna est veritas et prevalebit.*"

When absolutely pure, tri-nitro-glycerin is the most powerful

explosive known to man, but, to develop its full explosive force, it is necessary to expose it to a peculiar concussive shock, or vibration of its particles. When impure, either from accident or intentional adulteration with certain matters, it may be easily exploded. When mixed with other matters, such as wood-naphtha, nitro-benzole or nitro-toluol (page sixty-six), or when in the form of an emulsion containing twenty per cent. of water, and congealed, it is very difficult to explode. Its value as a blasting agent, depends not entirely on the enormous evolution of gaseous matter (one volume being converted into upwards of twelve thousand volumes), but also on the suddenness of that evolution. If this enormous expansion is resisted, heat (arrested motion) is developed, otherwise not. Diminish the suddenness of that conversion and you diminish its value as a blasting agent, and approximate it to projectile purposes. Our French neighbors have a clearness of description in these matters, that I avail myself of. Messrs. Roux and Sarrau describe two kinds of explosions that are capable of being effected with nitro-glycerin. One they designate as "an explosion of the first order." This is such an explosion as is produced by the detonation of a heavy charge of fulminate in the nitro-glycerin; it then yields a force equal to *ten times that of gunpowder.* But if it be lighted, it may then explode with a force equal to *twice that of gunpowder* only; this is called an "explosion of the second order."

Referring to dynamite, which, adulterated with nitrates of soda or potash, is now sold as "giant powder," "if some yielding matter, ochre, for example, be employed, the portion near the detonating fulminate suffers an explosion of the first order or class, the remainder, one of the second; that is, it develops a force only twice that of gunpowder." Abel found a great difference in the ability of various explosives, to start an explosion in nitro-glycerin. Chloride of nitrogen, although a far more violently explosive compound than fulminating mercury, did not explode nitro-glycerin with the same certainty as the fulminating mercury. I have noticed in blasting at the Hoosac tunnel, when, for economy's sake, the detonating cap was charged with only eight grains of a mixture of chlorate of potash, powdered catechu and sulphur, in lieu of twenty grains of

fulminate of mercury, that what Messrs. Roux and Sarrau designate as an explosion of the second order, followed; or, as the blasters express it, part exploded, part burnt, and part was blown out in vapor, to be inhaled by the miners. The drilled holes, seldom less than eight feet in depth, and frequently twelve feet deep, needed a heavier detonating charge than eight grains of the above described mixture, and it was an error to use such light exploders.

To couple nitro-glycerin with chemicals such as nitrate of potash, nitrate of soda, chlorate of potash, mixed with carbonaceous matter, which require an instant's time to develop into gases, would be like attempting to quicken the electric current by coupling it to the velocity of a locomotive. Our senses are incapable of measuring such degrees of velocity. When the trapper sights his prey, jerks his rifle, and pulls the trigger, the hammer, falling on the cap, crushes the fulminate, which explodes, and, finding vent through the nipple, reaches the breech, and then follows the explosive decomposition of the powder, in the following order: The sulphur burns, heating the nitrate of potash until oxygen is given off, which combines with the charcoal, converting it into carbonic acid. Being confined in the breech of the rifle, these changes are vastly increased in rapidity; when performed in the open air or in vacuo, with a diminished rapidity that enables us to note the action better, but with diminished force. Under the usual conditions of blasting, the confinement of tamping with clay is insufficient to retain the explosive force of the nitro-glycerin until its tardy neighbors, resin, paraffine, saltpetre, chlorate of potash, nitrate of barytes, *et id genus omnes*, have developed their force; or, to recall the simile of the electric current, the sounding-board fifty miles away is giving the signal, before the first puff of steam has reached the blast pipe. Give four men a weight to lift which requires the united force of all of them to raise, the exertion of force by any one, later than that of the others, wastes the force of all.

Holding these views, I have felt some impatience in studying the various "improved explosive compounds" for which there has been such a "furore" lately, judging from the records of the patent office. I understand perfectly well why Mr. Nobel

resorted to mixing nitro-glycerin with rotten-stone, for the patent relates,—"because it will absorb a greater quantity of nitro-glycerin than chalk, sand, sawdust, charcoal, etc.," and he simply added the term, "dynamite," as a trade-mark. The real reason for resorting to this mixture at all, however, was because of the accidents which had succeeded each other so rapidly in San Francisco, and Aspinwall; at Sydney, Australia; at Ridgefield, New Jersey, again and again; in Wales, whilst being teamed on the wharf; at Quenast, when the contents of a wagon exploded immediately on arrival at the quarries and while yet unloaded; and, lastly, the explosion of a number of cases of nitro-glycerin lying at the factory door ready for removal from Nobel's works at Stockholm. These spontaneous explosions disheartened Mr. Nobel, who, not being a chemist, but an enterprising engineer, resolved on some expedient to overcome the prejudice these explosions had created, and retain his commercial connection with mining interests. The following circular tells the tale:—

"*Nitro-Glycerin.*—The last two fatal accidents caused by nitro-glycerin, at the explosion of the factory of the Swedish company at Stockholm, and the catastrophe at Quenast, prove that the precautions absolutely necessary in handling this material cannot be secured; we therefore find ourselves compelled to cease shipping the same. Our customers, therefore, will have to satisfy themselves by substituting dynamite, which they can do the easier, as this latter article equals nitro-glycerin in regard to blasting under water,[1] in wet blasting for mines and quarries, is cheaper, and presents less danger in transportation."

ALFRED NOBEL & Co.

Hamburg, July 4, 1868.

This was followed by an order of the king of the Belgians, dated July 14, prohibiting its manufacture, storage or use in Belgium, in conformity with a report of the secretary of state, who so advised.

I repeat, I can understand how Messrs. Nobel & Co., having provoked these prohibitory laws, by failing to discover the

(1) This was before the mixtures of nitro-glycerin with inert matter, were so largely adulterated with nitrate soda. Now that manufacturers, influenced by the diminished profits caused by lowered prices, add these cheap salts to sell them as No. 2, No. 3, etc., the above remarks of Nobel's circular mislead.

causes of these spontaneous explosions, and remedying the fault of manufacture, made a virtue of necessity, and, in order to retain their commercial relations, invented the word dynamite, and mixed off their nitro-glycerin with an inert matter—fossil earth, or rotten stone—which masked the danger of the nitro-glycerin they failed to purify.

But, I protest against the assumption, that, therefore, nitro-glycerin cannot be prepared so as to remain unchanged, so as to be safe to use, safe to transport, and safe to store; and I refer to six years' work, and transportation on three hundred and upwards journeys of teams, throwing off of trains, teams rolling down bluffs, and of sloops, laden with five thousand pounds of nitro-glycerin, storm-beset, and blown out of their course by gales at sea, in support of my protest.

There are, however, cases where a diluted form of nitro-glycerin is economical, provided it is rendered to the miner at a cost proportionate to the percentage of nitro-glycerin it contains. Such is the case where the rock is hard and tough but fractures readily, when the drilling machine would batter up the steel drill of three-fourths inch diameter, and, for that reason, where a ten-foot drilled hole of one inch and a half diameter is more readily drilled than a hole of merely one inch diameter, notwithstanding its charge, of one inch diameter, of nitro-glycerin, distributed over a length of thirty inches, would be more effective than the same charge concentrated in a space of one and a half inches diameter and twelve inches in length; the former, or thirty-inch, column distributing its explosive force with more effect than when the bulk of the explosive is massed at the bottom or only through twelve inches of the drilled hole. In this latter case there is a waste of force at the bottom of the hole, and lack of force higher up; whereas, were the hole only one inch in diameter and thirty inches long, the force would be distributed over a greater distance and be more effectively applied. In such cases, the difficulty of getting steel of only three-fourths inch diameter to stand the hammering of the machine drill necessitates a hole too large for the nitro-glycerin, and an addition of inert matter, mixed with the nitro-glycerin to distribute its disruptive force over a larger area, is intelligible. But, to assert that sixty parts of nitro-glycerin are as

effective as one hundred parts, is a simple untruth, and this is what explosive-compound makers are guilty of when they declare compounds, which owe their force to the percentage of nitro-glycerin they contain, to be as strong as the pure liquid itself. At the Worcester explosion, one of these gentlemen actually swore that his compound was half as strong again as nitro-glycerin. It has been to me incomprehensible, that intelligent contractors, because they have witnessed a force exceeding gunpowder, it is true, but which, burnt on a cigar-box lid, leaves a heavy residue of saline matter, evidently left from the deflagration of nitrate soda, which is worth, even in its purified state, less than seven cents per pound, are content to pay one dollar a pound for the mixture, whilst they can obtain the pure explosive, without such admixture, for the same price. I have often wondered whether contracting was so remunerative that such simplicity could realize a living profit out of it. Careful observations of exploding force at the east end of Hoosac tunnel, convinced Mr. Francis Shanly that, when nitro-glycerin was poured into a drilled hole, without using a cartridge, the blast gave thirty per cent. better results than when the same quantity of nitro-glycerin was enclosed in an inch and a quarter tin cartridge; such was the cushioning effect of the tin cartridge backed by the one-fourth inch annular space of air! And the conclusions from the competitive tests at Hell Gate, were, that, when nitro-glycerin was mixed with absorbent inert matter, there was a startling loss of explosive force, as compared with the charges of nitro-glycerin pure and simple. Mr. Reitheimer informed me that, with one hundred and twenty-three feet of lineal drilled holes, and twenty-five pounds of giant powder, there was removed five and one-third cubic yards of rock; with only ninety-six feet of lineal drilled holes and eleven pounds of tri-nitro-glycerin, there was removed sixteen and one-third cubic yards of rock,—thus showing a force of six to one in favor of tri-nitro-glycerin. As these results were under Government supervision, it was urged that perhaps the most economical effects of giant powder had not been obtained. At the request of the legal adviser of the giant powder company, one of the adits was surrendered to the giant powder interest, to drill their own holes in such mode and direction as they deemed best, and

to charge them as they wished, but the results, even with these facilities, were not so favorable to the giant powder as had been obtained by the government employes, described above.

Whilst absent from the Hoosac tunnel, on a visit to the St. Gothard tunnel, in the summer of 1873, the culpable waste of nitro-glycerin and the careless direction of drilled holes (which could not be checked by the discharge of three foremen) at the West shaft headings, prompted the contractors to give giant powder a thorough trial, and this opportunity was nobly seconded by the liberality of the gentlemen entrusted with its sale, to the employes. Every hole was now carefully directed, and every charge was carefully adjusted to the burden. The result was far from satisfactory at first, but at length some of the blasters discovered that, by introducing into each drilled hole a small (?) cartridge of tri-nitro-glycerin, satisfactory results could be obtained by the giant powder, but not otherwise. The result was a considerable consumption of giant powder for several months.

As this was a result not conforming with those at Hell Gate, I made some observations as to the cause of these contradictory reports. At the Central shaft, tri-nitro-glycerin could not be replaced by giant powder, except for roof work. At the Central shaft heading, the effort to supplant tri-nitro-glycerin with giant powder was found to be too costly; still, in the roof, and on the bench, when giant powder was supplemented by a cartridge of tri-nitro-glycerin, good results were obtained. It became a matter of deep interest, to trace this effect to its cause. I arrived at the conclusion, that, as I had previously surmised, a good deal of difference in the economy of explosives would be found, in the correct distribution of the explosive force; that the drilled holes in the roof, were too large for the explosive used; that there was an unnecessary waste of force in one portion (the bottom) of the drilled hole, and a corresponding deficiency towards the outer end; and hence, when a far less powerful explosive was extended through a longer line, and effectually fired by a cartridge of tri-nitro-glycerin, the work could be performed effectually and at less cost.

I had for several years been aiming to manufacture an explosive mixture that would in no way diminish the sudden, complete

and instantaneous effects of nitro-glycerin, on which I relied as its principal component.

I knew, by the results at the St. Gothard tunnel, witnessed by myself, and confirmed by the contractor, M. Le Favre,—lithofracteur, sulphur, nitre and charcoal, burning (comparatively) slow, and nitro-glycerin flashing like the electric current; also, Nobel's giant powder failing to blast out of the heading a deeper hole than one metre (inches, 39.37), whilst we had been blasting out in the Hoosac tunnel headings, a depth of twelve feet with nitro-glycerin, and bottoming every time—that neither lithofracteur nor dynamite could compare with my explosive.

Beginning with glass blown into fine flakes, and moistened with nitro-glycerin, so that there should be no absorption, I finally settled upon finely divided scales of mica, or mineral isinglass (whose thickness I found by actual measurement to be from one-eighth to one-quarter of one-thousandth of an inch, only). This possessed the precious property of being very elastic, non-absorbent, and, as it consists principally of silica and alumina, was a chemical composition differing essentially from asbestos, which is a silicate of magnesia and lime; from kieselghur or rotten-stone, which is chiefly silica, with a little sulphate of iron; from soapstone, which is a silicate of magnesia; and since, in addition to these distinctive chemical characteristics, it differs physically, when compounded, from every other explosive compound—for the mixture is resilient to the rammer in charging a cartridge—it was such an inventive discovery as entitled me to the protection of a patent, and would thus enable me to manufacture without the incubus of an injunction. Practical experience only, by disinterested parties familiar with other explosive compounds, was needed to prove whether my anticipations of its superiority would be verified.

Tri-nitro-glycerin, mixed with the exceedingly finely divided scales, or laminæ, of mica, (whose measured thickness varied from one-eighth to one-quarter of a *thousandth* part of an inch) tore out more rock, dispensed with the extra cartridge of nitro-glycerin found necessary to develop the full force of giant powder, could be exploded even after the cartridge had been intentionally perforated throughout with holes and submerged under water for hours, suffered no diminution of the explosive

force of the nitro-glycerin so mixed with the laminæ, was fired perfectly by the ordinary nitro-glycerin exploder, and, to quote the report of Mr. John R. Roskrow, the superintendent of the Central shaft division, was "better, cheaper and safer" than giant powder, because it saved the expense and risk of carrying down the extra cartridges of nitro-glycerin; and, finally, it enabled the contractors to swell their estimate for March, 1874, to $42,616.00, for the Central shaft division alone, taking out three thousand and forty-four cubic yards of the hard, tough tunnel rock, with less than two thousand pounds of this mica blasting powder, thus furnishing a remarkable instance of the economical effects to be obtained in mining, by a due distribution of the explosive force. Such a result has never before been obtained in any of the divisions of this work. Further on will be found a tabular statement, prepared by Mr. Carl O. Wederkinch, assistant engineer in charge of Central shaft division, of the depths of holes, amount of charge, and rock blasted out with tri-nitro-glycerin, during one month, at the heading workings from the Central shaft.

Summed up, six years' experience at the Hoosac tunnel has proved conclusively :—

1st. That tri-nitro-glycerin, when properly exploded in sufficiently deep holes, is the most powerful, economical, and rapid-working blasting agent known.

2d. Mixed with *non absorbent* matters, its disruptive force is not diminished, and there is a true economy in such admixture, where a distribution of explosive force is indicated.

3d. Mixed with *absorbent* matters, such as rotten-stone, chalk, plaster of Paris, or ochreous earth, on the contrary, there is a diminution of disruptive force, except the firing be supplemented by a cartridge of nitro-glycerin.

4th. Nitrates, chlorates, resin, paraffine, and carbonaceous matters, mixed with nitro-glycerin, are useless additions, owing to their slower combustion, and, so far as concerns the purchaser, are adulterations.

5th. That Professor Abel's views, as to the importance of a sufficiently violent initial fulminating explosive, in order to

develop the full blasting force of the various nitro-compounds, are confirmed.

During the summer of 1873, I visited the St. Gothard tunnel, and examined the workings carefully at Goeschenen. I found the contractor, M. Le Favre, impressed with the idea that nitro-glycerin could not be safely handled, was using both Nobel's dynamite and Kreb's lithofracteur, but neither of these were able to blast out deeper holes than forty inches, although the rock was an easily-fracturing granite. The tunnel was being worked in five divisions, viz.: First—the heading proper, or central cut; this was seven feet in height and about six feet six inches in width. Second—the enlargement of this cut on the right thereof. Third—the enlargement of the same cut, but to the left thereof. Fourth—the right-hand half of the bench. Fifth—the left-hand half of the bench, which would complete the full size of the tunnel; but this portion was left for the present to serve as a tramway, to remove the rock from divisions one, two and three. The holes were drilled, for the cut, twenty-eight in number, and only forty inches deep, and were fired by uniform lengths of lightning fuse, leading from each hole to a central charge, into which a slow fuse was inserted. As soon as the slow fuse reached this central charge, into which from eight to nine of the lightning or fulminate fuses led, the explosion of eight or nine out of the twenty-eight drilled holes took place. And this was repeated; occupying, whilst I was there, thirty-five minutes to explode the twenty-eight holes. Even these shallow holes rarely bottomed. At the Hoosac tunnel, the cut is nine feet in height by nine feet in width, and twelve holes (see plate of system of drilled holes), each about nine or ten feet deep (instead of forty inches), are fired simultaneously with a frictional electric machine. At the St. Gothard tunnel, the drilling machines were so closely crowded, compelling the men to crawl over them, that the angle necessary to secure a good lift could not be obtained; and, to gain the same depth of drilled hole as at the Hoosac tunnel, it was necessary thrice to introduce and thrice to remove the machines, making connections, etc., etc. The frequency of firing was difficult to regulate, and lost much of the men's time; but, as the rate of wages was very low, this, except for delaying the work, was not so impor-

Table of explosive mixtures, by Messrs. Chas. Girard, Millott and Chas. Vogt, Paris, Comptes Rendus de l'Acadmie, t. LXXI, No. 20.

COMPOSITION.		BENEATH A WEIGHT OF TEN AND ONE-HALF LBS., AVOIRDUPOIS, FALLING FROM A DISTANCE OF			OBSERVATIONS.
		65 INCHES.	40 INCHES.	20 INCHES.	
Pure Silica	3.00	Explodes with difficulty	Explodes—still more difficulty	Explodes still more so	These proportions give a powder perfectly dry.
Nitro glycerin	1.00				
Silica	3.00	Explodes well	do easily	do	Pulverulent, but moistens paper.
Nitro-glycerin	3.00				
Silica	0.40	Explodes promptly	do well	do	Very damp and saturates paper.
Nitro-glycerin	3.62				
Silica (residue from alum factories)	2.70	Explodes well	do well, but partially	do with difficulty	A pasty mass and saturates paper.
Nitro-glycerin	3.00				
Alumina	1.20	Explodes well	do rather difficult	do with great difficulty	Semi-pulverulent, moistens paper.
Nitro-glycerin	1.00				
Alumina	3.00	Explodes with difficulty	do requries sevrl. blows	Slightly explosive	Dry powder, not moistening paper.
Nitro-glycerin	1.00				
Kaolin, washed & ground	5.40	Explodes well	do	Explodes with difficulty	Moistens paper.
Nitro-glycerin	3.40				
Tripoli, washed	2.11	Explodes well	do	do with difficulty	Moistens paper.
Nitro glycerin	2 68				
Clay, ground	2.25	Explodes well	do well	do	Pasty mass, saturates paper.
Nitro-glycerin	2.05				
Gypsum, ground	8.50	Explodes well	do in portions	Still explodes in portions	Pasty mass, moistens paper.
Nitro-glycerin	3 68				
Bricks, ground	8.00	Explodes well	do	Explodes with difficulty	Moistens paper by compression.
Nitro-glycerin	4.15				
Ethal	0.50	Explodes with difficulty	do	do with difficulty	Very moist pasty mixture.
Nitro-glycerin	1.00				
Ethal	1.00	Explodes with great difficulty	do	Does not explode	Powder almost dry, moistening paper slightly.
Nitro-glycerin	1.00				
Sugar, powdered	0.50	Explodes in close cartridge but not alone	do with difficulty	do do do	Almost liquid.
Nitro-glycerin	1.00				
Sugar, powdered	1.00	Explodes with difficulty	do with great difficulty	do do do	Very thick liquid with crystals of sugar.
Nitro-glycerin	1.00				
Sugar, powdered	3.00	Explodes very badly	Does not explode	do do do	Powder almost dry, moistening paper.
Nitro-glycerin	5.00				
Sugar, in lumps	1.00	Explodes with difficulty	do do do	do do do	Nitro-glycerin almost absorbed by sugar.
Nitro-glycerin	2.00				
Sugar, in lumps	3.00	Explodes not at all	do do do	do do do	Wholly absorbed.
Nitro-glycerin	2.00				
Glycerin	1.00	Explodes with difficulty	Explodes badly	do do do	These liquids separate in a short time.
Nitro-glycerin	3.00				
Alcohol, methylic	3.00	Explodes not at all	do do	do do do	Do not separate.
Nitro-glycerin	1.00				
Oil	3.00	Explodes only with difficulty	Does not explode	do do do	Forming an emulsion, separating in time.
Nitro-glycerin	3.00				
Nobel's Powder { Nitrate Barytes, Resin, Nitro-glycerin,	0.70, 0.10, 0.20	Explodes well	Explodes	Requires several shocks	Moist powder, soaks into paper.
Nobel's Powder { Nitrate Barytes, Pitch, Nitro-glycerin,	0.68, 0.12, 0.20	Explodes well	do	Explodes when compressed	Moist powder, soaks into paper.
Nitro-glycerin, alone		Explodes	do	do from 10 inch fall	Liquid.

tant as with American rates of wages. The penalty for every day beyond the time of contract for the first six months, is one thousand dollars per day; for the second six months, two thousand dollars per day; whilst the bonus for every day within the term, is to be one thousand dollars per day extra. On paper, the idea of working five divisions or gangs of men seems to promise rapid progress, but it needs excellent discipline and very perfect organization. There is such a crowding at the first cut, that the machines cannot be set to work at the angle necessary to do the best work; and, of course, even if they possessed the explosive capable of tearing out holes ten and twelve feet deep, the drill could not be set to penetrate at the suitable angle to insure the bringing out of the whole wedge. M. Le Favre, whose courtesy and facilities for my observing their work are here acknowledged with grateful thanks, observed: "*Si vous pouvez entreprendre le forage, le chargement, et l' allumage des trous de trois metres, et manipuler le nitro-glycerin sans accident, naturellement nous sommes a vos pieds. Mais nous pensons que nous devons instruire les Americains, au lieu d' etre instruit de l' Ouest.*" The reader, after perusing the tabular statement of the Central shaft division of the Hoosac tunnel, where lineal advance of seven feet six inches, instead of two feet six inches, as at the St. Gothard, has been averaged at each blast, must judge whether the opening paragraph of this work is not justified by the accomplished facts.

And here I may remark, that, as regards the transportation of nitro-glycerin, I have never attempted to secure transportation by railroad, except where it was being used on the line; or by steamship, preferring to use my own teams, whose long and lonesome journeys have sometimes occupied twelve days before reaching their destination. When shipping to Mr. R. Mc Greevy, Messrs. Berlinguet & Cie., at Metapedia, Dalhousie, in the bay of Chaleurs, the time occupied between leaving the magazine at North Adams, and reaching the Intercolonial railroad, has averaged twenty-four days, with never an accident; at Ticonderoga, a team rolled down a bluff; on the Chesapeake and Ohio line, the car jumped the track and was dragged over the ties, some of which were two feet ten inches apart (measured distance), the roadway not then ballasted, for a distance of six hundred and

eighty-four feet, without explosion. In France, the manufacture of gunpowder and explosives is a monopoly of the government. In Belgium and Prussia, the various mixtures of nitro-glycerin with inert matters, are classed with gunpowder. In Belgium, the barrels are required to be surrounded with straw, so as not to leave an opening exceeding one square centimetre uncovered. The exploders are interdicted from being attached to the cartridges. In Austria, after numerous experiments, they have concluded that there is no more danger in their transportation than with petroleum, alcohol and ethers. Certain precautions are required as regards storing, making up the trains, etc., and it is compulsory on the consignee to remove it on arrival. In England, a recent decision authorizes the railroads to carry it. But, in all of these countries, nitro-glycerin is under a ban, that can only be thoroughly dispelled so soon as some important engineering work shall demand the most powerful, the safest, and, at the same time, the most uniform, as to composition, of all explosives that can be manufactured—tri-nitro-glycerin.

Since the article on the Martello tower, at Hythe, England, was in type (see pages thirty and thirty-one) two more attempts have been made by the Royal engineers, from which it would appear that they abandoned the Wheatstone magnetic exploding machine, the Abel fuse, and the electric wires, preferring to use the tape fuse. No mention is made of the quantity of gun cotton used, perhaps because it was so great; but it will be seen that the series of attempts to blast down this brick tower with Abel's gun cotton, have not been attended with success.

Second Attempt, Feb. 11, 1874.—"Another attempt to blow down the ruins of number ten Martello tower, with gun cotton, on Wednesday, proved ineffectual. Between eleven and twelve o'clock, engineers were busily engaged at the tower, and shortly after that hour an order was given by the commanding officer for sentries to be placed five hundred yards distant, to prevent any persons approaching the ruins. However, the duties of the men were far from onerous, as no intimation of the experiment had been given, and consequently the spectators were few. It was not until a severe shock as of an earthquake was felt, and with it simultaneously a loud report, that those in the town became aware of the fact, so close had everything

been kept. About half-past twelve several persons were observed to enter an aperture in the ruins, and in a few minutes come out, and after descending the ladder run towards the walls of fort Twiss. Five minutes elapsed, and then a loud explosion took place, a cloud of smoke burst forth, the earth trembled, and the tower remained apparently as before. On inspection, it was found to have undergone a considerable shaking, large portions of the brickwork were displaced, the north-east side having been mostly affected. The gun cotton was fired by a fuse, and not by the electric machine as before."

Third Attempt, Feb. 14, 1874.—"On Saturday, the engineers tried another experiment on the ruins of number ten Martello tower. In the holes, made in several blocks, gun cotton was placed, and was fired by fuses. After five or six minutes had elapsed from the time of their being lit, puffs of smoke shot out as from a cannon's mouth, from the perforated blocks. The effect was not great, as a small portion only of the brickwork was displaced. Afterwards some gun cotton was placed inside the ruins and fired, and that did not bring down the massive sides. Of course the ruins had received a severe shaking, and were therefore rendered more dangerous. Col. Nicholson, commanding the Royal engineers, Shorncliffe camp, has since issued a notice to the public, cautioning them not to approach the tower."

And yet the London *Times* jauntily remarks, Jan. 19, 1874:

"When this explosive substance (gun cotton) is made according to the Abel process it possesses three characteristics which render it peculiarly adapted to military engineering operations. It can be stored and transported in the wet condition—that is, saturated with moisture—in which state it is absolutely uninflammable. While in this wet state it will explode with terrific violence if a small portion of dry gun cotton be detonated in contact with it. Lastly, it may freely be brought under fire without fear of accidental explosion. The Government works at Waltham Abbey are now in full operation, and, under the active superintendence of Colonel Younghusband, R. A., large stores of gun cotton, for torpedo and other purposes, are in course of formation in different parts of the kingdom. A small quantity has also been sent to Ashantee for use in connection with military engineering services.

"Dynamite is made by mixing nitro-glycerin with a porous, infusorial earth, known in German as "Kieselguhr." The earth absorbs the oil, and the result is a plastic, putty-like substance of a brick-dust color, containing about seventy-five per cent. of nitro-glycerin, and twenty-five of absorbent earth. Dynamite is manufactured in this country by the British Dynamite Company, who have erected extensive works at Ardeer, near Glasgow. They make two descriptions—number one, or the ordinary "Kieselguhr" article, which contains about seventy-five per cent. of nitro-glycerin, and a cheaper quality, called number two, which contains about twenty per cent. of nitro-glycerin mixed with nitrate of potash and powdered charcoal.

"Lithofracteur is, practically, dynamite under another name. It generally consists of nitro-glycerin, sandy earth, powdered coal, sulphur, sawdust, and nitrate of soda or nitrate of baryta.

"Lithofracteur appears to have been occasionally used by the German military engineers during the war of 1870, and its employment during the siege of Paris was specially referred to by the military correspondent of the *Times*. The composition of these several substances is now so universally known, that it is perhaps unnecessary to give it; still, it is convenient for our purpose to refer briefly to it.

"Our Service is, of course, free from this danger, because the agent we use, gun cotton, is not liable to explosion when struck by a bullet; and, unless steel-plating or some such protective means be resorted to, we have little doubt that other nations will, before long, follow our example, and adopt a material which in lightness, in the security with which it may be handled or transported, the rapidity with which it may be applied, and the destructive effect it is capable of producing, is admirably adapted for the purposes of the military engineer."

There could hardly be a more complete answer to the "three characteristics which render gun cotton so peculiarly adapted to military engineering operations," than the three failures at number ten Martello tower; and "our Service" will do well to look further into explosives, if, without an enemy to disturb their equanimity, they make three failures in blowing down an old brick tower.

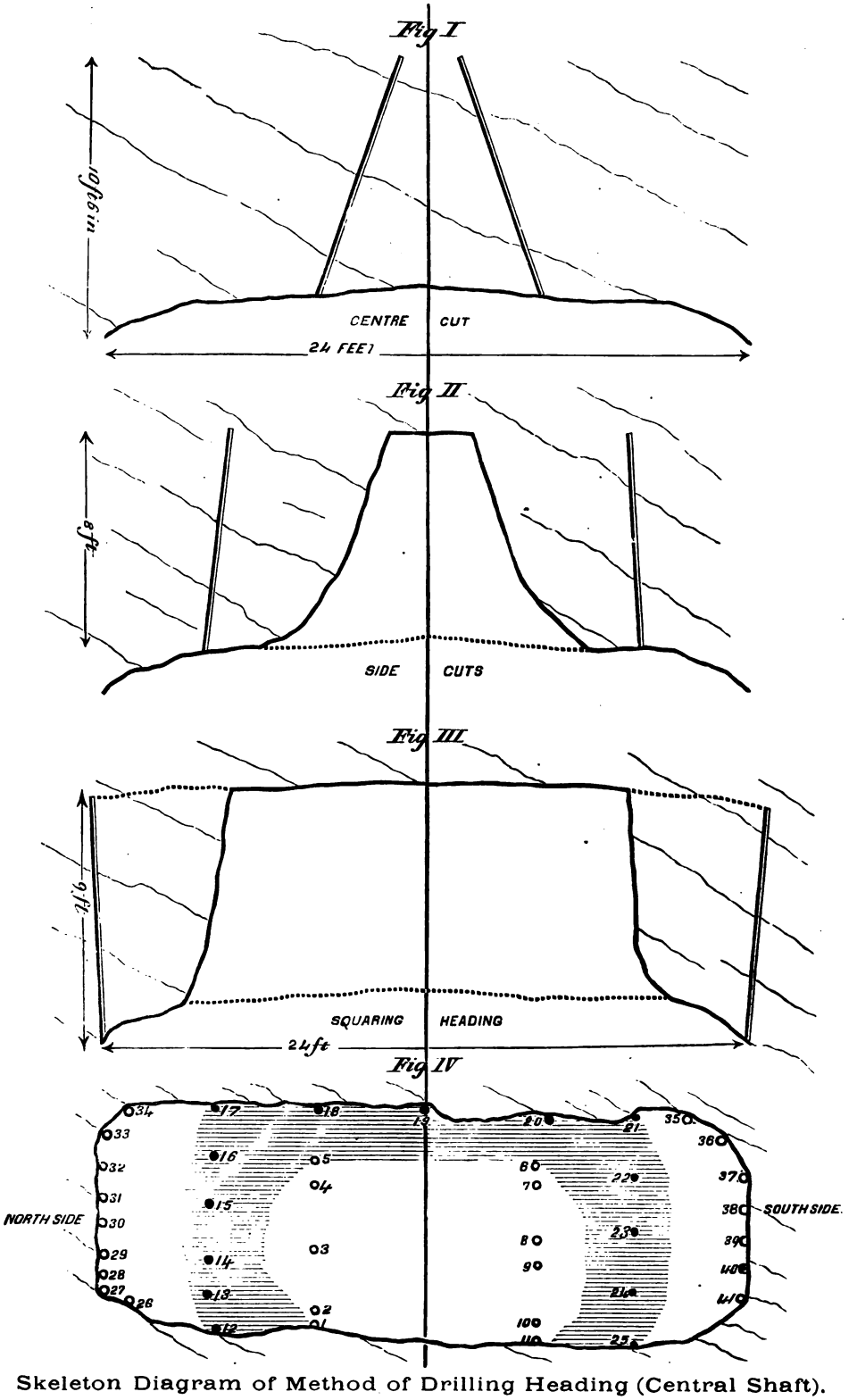
CHAPTER VI.

SYSTEM OF WORKING AT HOOSAC TUNNEL—HEADING AT WEST END—WORK OF THE THREE SHIFTS OF MEN EVERY EIGHT HOURS—DRIVING FIRST BENCH—DRIVING SECOND BENCH—TAKING OUT DITCH—RUNNING HEADING AT EAST END ON GRADE—STOPEING OUT ROOF AT EAST END—FIRST STOPE—SECOND STOPE—MOVABLE PLATFORM—HANDS EMPLOYED—PAY-ROLL—LIGHTLY CHARGED EXPLODERS UNPROFITABLE—ECONOMY OF MICA BLASTING POWDER—TENSION OF GASES AND SPEED OF PROJECTILES—LOSS IN CONVERTING GUN POWDER INTO FORCE—LOSS IN CONVERTING COAL INTO FORCE—WASTE OF NITRO-GLYCERIN—CORRECTING ERRORS OF FOREIGN WRITERS—BERTHELOT'S ESTIMATED FORCE OF EXPLOSIVES—EXPANSION ABSORBS HEAT—IRON PIPE EXPLOSION—RESISTANCE DEVELOPS HEAT—NITRO-GLYCERIN "THE IDEAL OF PORTABLE FORCE"—A PROFESSOR'S PREFERENCE AND PREJUDICES—M. F. PAPILLON—RAPIDITY OF EXPLOSION THE ESSENCE OF DISRUPTIVE POWER—NITRO-GLYCERIN AND GUN COTTON.

WE have briefly sketched the mode of working at the St. Gothard tunnel, (page ninety-two) the heading being attacked in three divisions, and the bench in two subsequent workings. At the west end of the Hoosac tunnel, the system has been to first make a cut, that is, to drill two series of five or six holes each (see plate), about nine feet apart and vary-

ing from nine to twelve feet in depth, each series converging towards the other, and the drilling of which usually occupied from six to seven hours, depending upon the hardness of the rock or the quantity of quartz with which it is interspersed. A reference to the plate will discover these holes numbered from one to eleven. These being loaded and the wires connected, are fired by friction battery, and, as soon as the rock is removed, the drill carriages bearing the machine drills are advanced to the heading; the next series of fourteen holes, numbered twelve to twenty-five, are then drilled, and, if time admits, occasionally one, two or three of the sixteen holes numbered from twenty-six to forty-one are drilled. Usually, only series numbered twelve to twenty-five are drilled in the second shift. The fourteen holes are then loaded, the wires connected and fired as before. Again the rock is loaded on the cars to make way once more for the drill carriages, and again the machine drills are in full operation. As soon as the last series of holes, numbered on the wood-cut twenty-six to forty-one, are completed, these in like manner are loaded, the wires connected and fired by the friction battery. The effect of these three blasts consummated in twenty-four hours, is to advance the heading nine feet in height by its full width of twenty-four feet, making an average net advance of seven feet six inches of heading proper. During the progress thus made by three gangs of workmen, in their rear, and about four or five hundred feet distant, other gangs have been working at the bench; that is, drilling six holes, each seven feet deep; two of these range each about four feet from the face of the bench, close to and perpendicular with each side of the tunnel, whilst two more holes (four feet behind these first holes) are similarly drilled; and, lastly, two others, eight feet from the face, eight feet from each other, and eight feet from the side walls of the tunnel, are also drilled, making six holes in all. These are charged, wires connected and fired by the friction electric machine, the result being to lower the floor of the bench about seven feet in depth, and the full width of the tunnel. Behind the first, another gang is proceeding in precisely the same manner, whose work fully completes the full area of the tunnel, twenty-four feet in width and twenty-two feet in height.

When sufficient advance permits, the ditch is then proceeded



Skeleton Diagram of Method of Drilling Heading (Central Shaft).

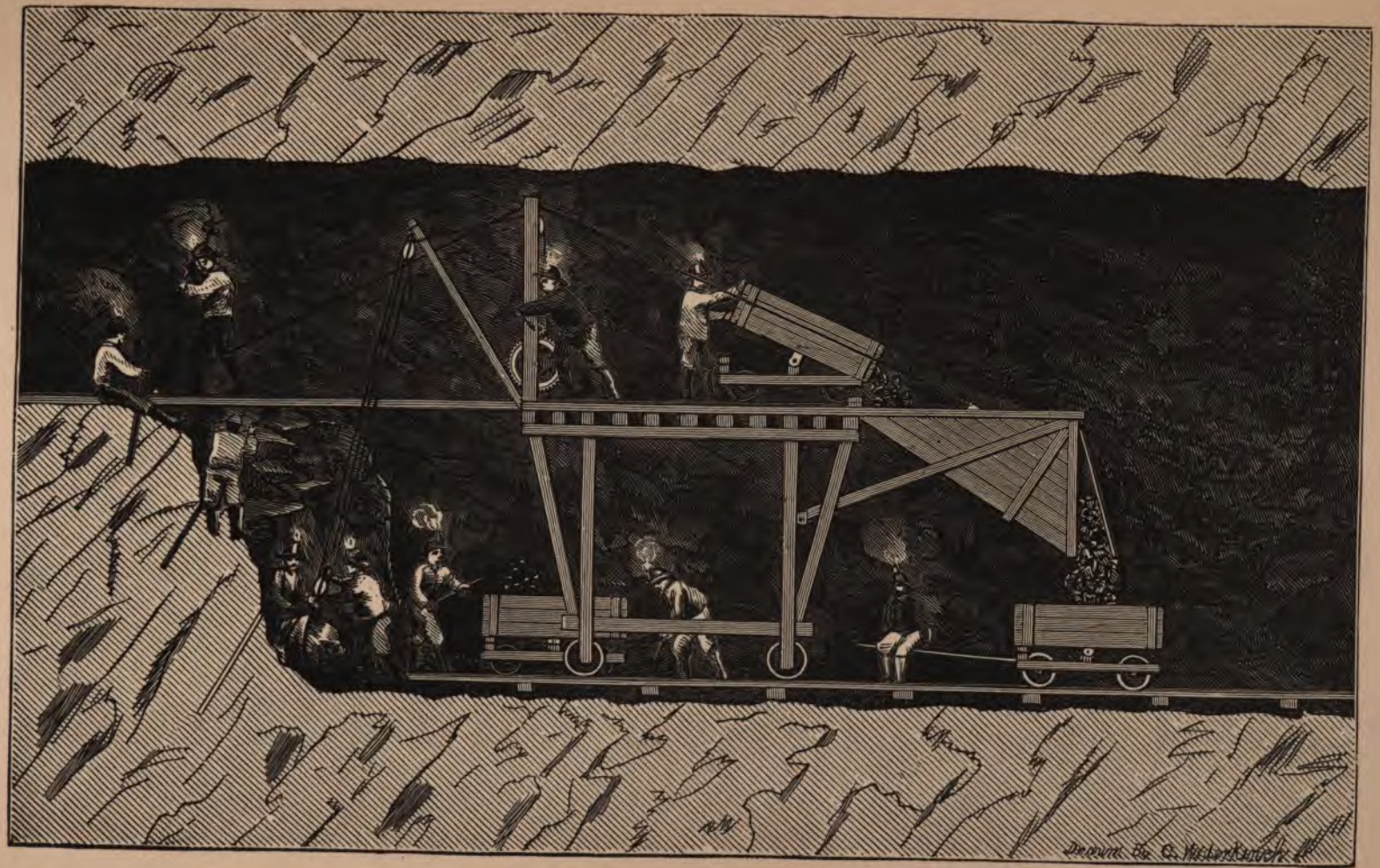
with, and here an opening in the sole or floor of the tunnel five feet wide and four to five feet in depth, is channeled out, to serve as an adit for the water. The only variation between the mode of advance at the East as compared with the West end, was, that, at the East end, the heading was commenced on grade, and, instead of taking out two series of benches and a ditch, two series of stopes were taken from the roof, and, instead of six holes being drilled in a nearly perpendicular direction, as at the bench, eight holes were drilled horizontally in the roof, in a direction parallel with the grade of the tunnel, and the rock was thus thrown down on to the track from the roof overhead, instead of being thrown out as from a quarry. This necessitated a movable platform (see plate) to enable the miners to get at the roof, and involved moving same up to the work after a blast, and from the work immediately previous to a blast. The ditch was then worked out precisely as at the West end.

At one period, there were four gangs of men working simultaneously at these headings, i. e., one from the west towards the Central shaft, one from the east towards the Central shaft, a third gang working to reach the West end from this shaft, and the fourth gang working towards the East end from the same shaft. This was independent of the two gangs stopeing out roof in the eastern division, and two gangs driving bench at the western division. Reckoning sixteen men to each of these eight gangs, who worked in eight hour shifts, the three shifts would count up three hundred and eighty-four men continuously employed, besides plate-layers, rock-men, engineers to the cages, to the locomotive, to the compressors, blasters, dumpers, blacksmiths, helpers, machinists for repairs, time-keepers, etc., etc., requiring, to compensate for sickness, a number closely approximating to nine hundred souls; these required direction, supervision, provision of materials—and, lastly, monthly pay, from a pay-roll amounting from $40,000 to $60,000 per month, exclusive of supplies. The average of the work may be said to have consumed two to three pounds tri-nitro-glycerin per cubic yard of rock in the headings, and, from six to twelve ounces per cubic yard at the bench-work, and stopeing out roof; this expenditure was bettered in 1874, by greater care in direction of holes, closer supervision by foremen, a stricter accountability as to the explo-

sive consumed by the several blasters at each division, and the substitution of mica blasting powder for the bench and stopeing out work. The reader will consult the wood cuts for the several operations above described.

In blasting the above charges, a very light initial exploder was used, viz.: about eight grains only of a mixture of chlorate of potash, powdered catechu and sulphur, confined in a copper capsule—an initial explosive force neither suited to the explosive used, nor, in my opinion, capable of developing, perfectly and completely, the force stored up in nitro-glycerin or dynamites; the impression of the blasters being that if an explosion followed the electric spark, then the explosive must have developed its full force—an expensive error for the contractors. The hurry, drive and numerous details connected with the work, overshadowed suggestions offered, and altogether covered up the proofs of incomplete explosion which were afforded by difficult respiration to the miners every now and then, i. e., part exploded, part burnt and part volatilized, fouling the air; this, however, the admirable ventilation rapidly dissipated, and it was regarded as a minor inconvenience. On intimate terms with the manufacturer of the exploders, any suggestions from the manufacturer of the explosive were received by the superintendents in charge of the work, as of questionable value, and were suffered to pass unnoticed, and the idea that a heavy charge of fulminate in the exploder would save twenty per cent. of the explosive, was disregarded, possibly disbelieved. The great economy of mica powder, composed of elastic scales of mica mixed with nitro-glycerin, in February, March and April, proved conclusively that distribution of force and complete explosion, are elements that a contractor must not omit in the economy of working. Here was a saving that had never been hoped for and which diminished the cost of the explosives consumed.

The doctrine of correlation of forces, first indicated by Benjamin Thomson (Count Rumford), when he heated water to boiling by the friction of boring a cannon, and his experiments on the tension of gases given off by exploding powder, in 1792, have received much attention of late years, and have led to an examination of the maximum tension of gases given off by various explosives. In the United States, in 1857, Major Rodman,



Driving Bench Work and Dumping from Heading (West End).

and, in England, from 1869 to 1871, a commission experimented —the latter with the following results:—

Explosive.	Size of Grains.	Time.	Pressure.	When projectile had reached a distance of
Rifle powder	Each gr. av'ge. ¾ gr.	1 / 50.000 of a sec.	4090 ats.	6 inches
Pebble "	" " " 30 to 80 grs.	" "	2430 "	30 "
Pellet "	" " " 77 "	" "	2730 "	10 "
Prismatic powder (Russian)	" " " 600 "	" "	3230 "	22 "

The weight of the ball was one hundred and seventy-five pounds, of the charge thirty to thirty-five pounds, and, at the distance given in the last column, a velocity of one thousand three hundred and fifty feet per second was averaged.

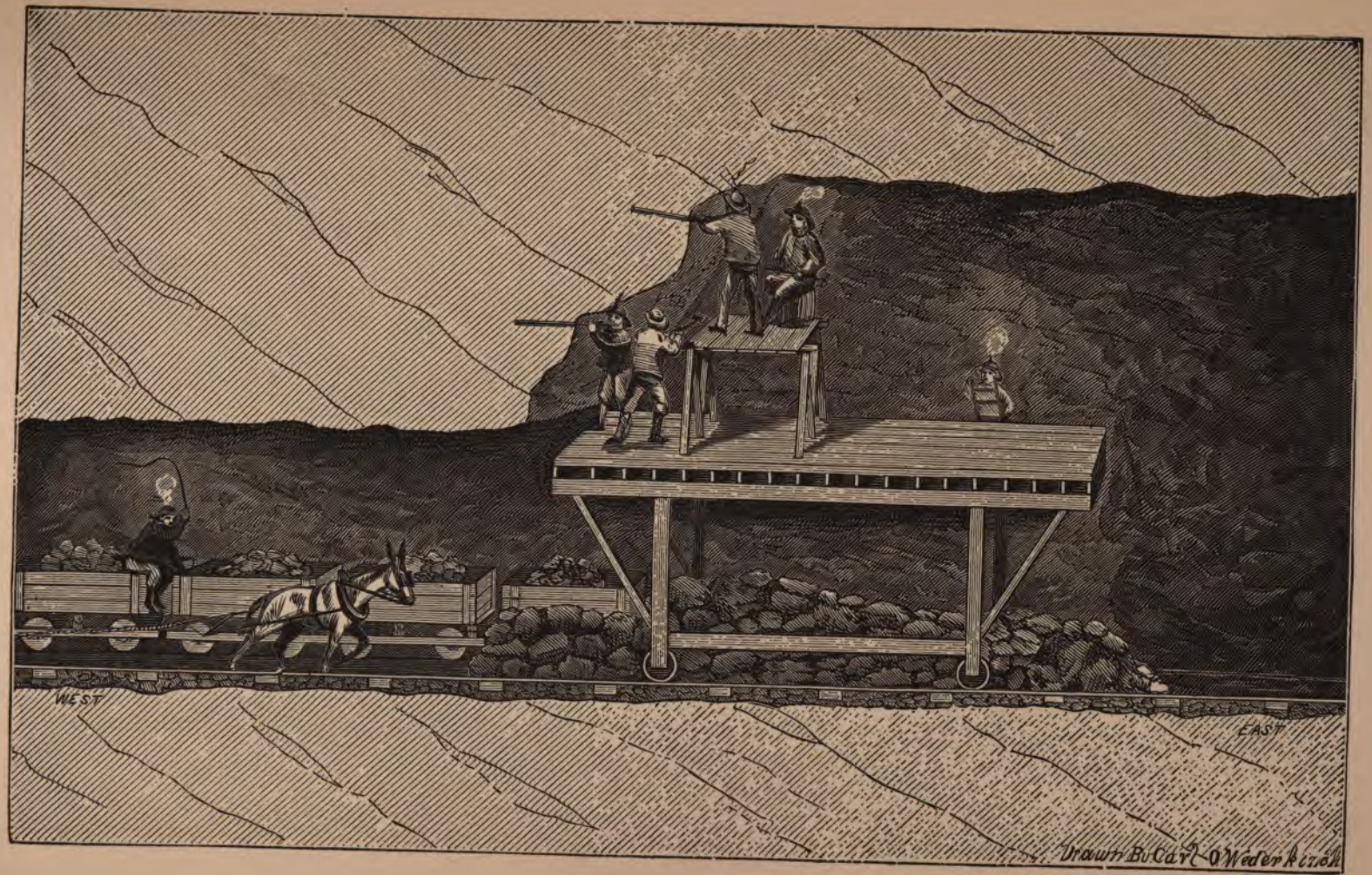
In the above experiments, it was observed that the pebble powder strained the breech of the cannon less than either of the others. Probably only one-third of the powder is ever burnt before the projectile leaves the cannon, and a great part of the elastic or impelling force of the gases is converted into heat, caused by their compression as developed, suggesting the conclusion that only one-fifth, or at most one-fourth, of the force developed is utilized in propelling the ball. An analogous loss is found in the consumption of fuel to develop power in low-pressure engines, when only two per cent. of the force contained in the coal is actually transmitted to the shaft for useful work, and in high-pressure engines not more than six or seven per cent., the remainder being wasted in imperfect combustion, in resistances overcome, in friction, loose boxes, leakage, heating of parts of the machinery, so that the imperfect adaptation of the means to the end actually wastes upwards of ninety per cent. of the power that is stored up in the fuel consumed. If, then, five hundred years after gunpowder was known, our utilization of its force is so incomplete, it is not to be wondered at that nitro-glycerin, during merely six years' experience, should have been wasted to some extent; but, nevertheless, it has proved a remarkable success, and, although imperfect manufacture and the fear and dread thereby occasioned have hitherto prompted other nations to abandon its use, the reader may judge how competent are those who have condemned it, when they assert, in contradiction of the truth, that: (1) "Nitro-glycerin congeals readily,

(1) Revue des deux mondes, Juilet, 1873, p. 423.

which is very disadvantageous, for *in congealing it appears to acquire a greater tendency to explode spontaneously.*" "Explodes *more easily than* gun cotton, and is more dangerous in its manufacture than gun cotton. Three capital errors.

Resuming the train of thought on explosives, and the means of measuring their force, let us regard this force as the equivalent of the volume of the gases, into which the explosive is decomposed, intensified by the temperature caused by resistance. Reducing the temperature of the gases evolved to 32° F., one volume of powder will give two hundred volumes of gaseous matter (if completely burnt); one volume of nitro-glycerin gives eight hundred volumes of gaseous matter, likewise reduced to 32° F. In riveting together the six atoms of carbon, five of hydrogen, three of nitrogen and eighteen of oxygen, which go to form one equivalent of nitro-glycerin in its congealed or crystallized state, a certain mechanical work has been accomplished, winding up together, as it were, an infinite number of small springs, which release themselves and give out their reserved energy in the act of exploding; this, if resisted, develops heat and disrupts a resisting medium, whilst in vacuo the gaseous matter would absorb the heat of combustion and simply fill the vacuous space without developing heat. In the explosion of two thousand pounds of nitro-glycerin in a frail boarded magazine, the force was so great, so sudden and so quick, and the resistance offered by the magazine and the atmosphere were so trivial, that there was no combustion of the finest splinters, nor even of the filaments of woolen or cotton materials that were carried perhaps five hundred feet from the focus of explosion, nor did this force explode twelve cans filled with congealed nitro-glycerin (see wood-cut), within ten feet of this explosion. Exploded in an iron pipe however, the fragments of the pipe will be found *heated by the resistance* it has opposed to the volume of gases set free. Without any resistance, the gases, by their explosion, absorb the heat developed during decomposition.

M. Berthelot, in his researches on explosive matters, with a view to judge *a priori* of the power of any explosive, calculates from the chemical composition of the explosive the volume of the gases produced by the explosion, and the quantity of



"Stopeing out" Roof Enlargement (East End).

heat developed in the reaction. The product of these two numbers, as he conceives, gives, within a certain range, its explosive force.

I here transcribe M. Berthelot's figures. The first column indicates the heat furnished by one kilogramme (two pounds three ounces Avoirdupois) of the matter under consideration, the second column the volume of gases disengaged, and the third the resulting product of these two quantities, serving as an approximative estimate of its explosive power:

	Heat.	Volume of Gas.	Estimated Explosive Force.
Blasting powder,	509	0.173 litre	88
Artillery "	608	0.225 "	137
Sporting "	641	0.216 "	139
Powder, Nitrate of Soda for its base,	764	0.248 "	190
Powder, Chlorate of Potash for its base,	972	0.318 "	309
Gun Cotton,	590	0.801 "	472
Picric Acid,	687	0.780 "	536
Picrate Potash,	578	0.585 "	337
Gun Cotton mixed with Chlorate of Potash,	1420	0.484 "	680
Picric Acid " " " "	1424	0.408 "	582
Picrate " " " "	1422	0.337 "	478
Nitro-glycerin,	1320	0.710 "	939

The above table is very instructive. Sporting powder gives out more heat than either blasting or cannon powder, nevertheless, it scarcely exceeds the latter in explosive force. Blasting powder gives least heat and least force, containing much less nitre. Theory here coincides with practice. Again, chlorate of potash, added to other explosive materials, doubles the heat of combustion, but the resulting effect is not so striking, for the reason that the substitution of chlorate in lieu of the other matters, diminishes the volume of gas disengaged. Gun cotton develops nearly as much heat as powder, but, in addition, it also develops so much gas, that its initial energy becomes more than thrice that of powder. Lastly, nitro-glycerin, which the author[1] I am quoting describes as "*really the ideal of portable force:*" "*It burns completely, without residue, in fact, gives an excess of oxygen; it develops twice as much heat as powder, three and a half times more gas, and has seven times the explosive force, weight for weight, and, taken volume for volume, it possesses twelve times more energy.*" M. Berthelot says further, "Theoretically, there is but one substance that can surpass it, i. e., liquefied protoxide of azote, mixed with ether or other liquefied carburets; these mixtures range up to fourteen hundred degrees of heat, and their energy is expressed by the number one thou-

(1) Mons. Fernand Papillon.

sand. But it is commercially impossible to obtain the instantaneous explosion of such mixtures formed with liquefied gases, because it would be necessary to compress these gases into a liquid form, preserve them in vessels hermetically sealed, in which form they must be mixed and fired, otherwise only a force of about ten to twenty atmospheres could be obtained."

There is one element which seems to have been ignored in the preceding calculations of M. Berthelot, but which, nevertheless, exercises a vast influence on explosives, viz.: the time in which an explosive is converted into gaseous matter. In fire-arms, it occupies one-sixtieth of a second for a ball to reach the muzzle; a loose yarn of gun cotton, if gently set on fire by a spark, smoulders slowly away, but burns rapidly if lit by a flame. A charge of gun cotton in blasting a mine or a quarry or in a rifle, explodes after the manner of gunpowder; but, if fired by a suitable charge of fulminate of mercury, it "goes off" with terrific violence. Damp gun cotton under water can be fired by means of a dry portion or cake of compressed gun cotton fired primarily by a charge of fulminate of mercury, and will be as terrific in its explosion as dry gun cotton, in these respects being analogous to nitro-glycerin, which, if soaked into blotting paper, smoulders out, burns rapidly with a voluminous flame if lighted by a flame, explodes violently if fired with a suitable charge of fulminating mercury or struck on an anvil, and is equally powerful in its explosive force whether covered by water or open to the air. Nitro-glycerin, however, possesses this valuable property, that, when congealed (at 45° F.), it is most difficult to explode even with fulminate of mercury, and requires a very heavy charge of fulminate enveloped in the mass; even then it cannot always be exploded.

The rapidity of decomposition of these explosives when they develop their utmost energy, has been estimated for gun cotton as traveling nearly twenty thousand feet in a second, and for nitro-glycerin at a still more rapid velocity. On velocity of explosion a variety of results depend (see page eighty-five); indeed, for mining purposes, velocity of explosion is the very essence of disruptive force.

Should the manufacture and use of gun cotton ever be accurately compared with the manufacture and use of nitro-glycerin,

these two explosives will be found to possess approximating analogous properties, but just so long as these or any other explosives are described as "treacherous or dangerous," qualities belonging to man's ignorance in preparing or using them, and wholly inapplicable to inorganic or organic materials,—just so long shall we be amused, surprised or pained, as the case may be, with errors, unreliable statements, or terrible accidents. Such phrases as "accident with fire-arms," "spontaneous explosion," "spontaneous combustion," which serve to cover up recklessness, neglect, or want of knowledge, may be pardoned in a tyro; but are we to describe the criminal carelessness of pointing a loaded gun and pulling the trigger, under the supposition that it is unloaded at the time, as an "accident," or to term the careless heaping of cotton waste, saturated with oil, in the corner of a picking room "spontaneous combustion," when every mill-hand knows perfectly well that such an act would ensure the burning of the mill. Such loose language bars progress. To undertake the running of a gun cotton factory, or the manufacture of nitro-glycerin, without previous study and preparation, will be bad for the owners and the hands employed, delay progress and can only benefit the undertaker—and him not much.

Mr. Abel describes nitro-glycerin as "dangerous, treacherous, and liable to explode at any moment spontaneously." M. F. Papillon pathetically remarks, "if nitro-glycerin were not so dangerous"—thus begging the question. M. Nobel & Cie., "it having been found impossible to command the conditions necessary to handle" their nitro-glycerin, advise their friends "to be content with dynamite."

To the first, I reply, that there is no treachery in Nature's laws, nor in chemical combinations; there may be ignorance of these laws, and their violation may involve the death penalty. The professor's language is unphilosophical and suggests a prejudice against nitro-glycerin and partiality for gun cotton, with which latter his mortifying experience has misled him. His idea seems to have been: Gun cotton has been very dangerous and very treacherous, as regards my expectations; now, as nitro-glycerin is very much more powerful than gun cotton, *ergo*, I

regard it as very much more dangerous and very much more treacherous than gun cotton—a fallacy.

M. F. Papillon, whose admirable article, (except for the untrue assertions, that nitro-glycerin seems to acquire a tendency to explode spontaneously when congealed, that it explodes more readily than gun cotton, is more dangerous to prepare than gun cotton—three assertions devoid of truth, for it is very difficult indeed to explode solidified or congealed nitro-glycerin and requires some skill to explode it in a liquid state in mining; I have beside me a cartridge which, although armed with a very powerful exploder, containing fifteen grains of fulminate, which was exploded in the cartridge, the latter being only half filled with nitro-glycerin, yet it did not explode, owing to the exploder not being immersed in the nitro-glycerin, although the exploder blew the cartridge into ribbons); Mons. Fernand Papillon, to whose article I am indebted for valuable matter in this book, simply gives the current literature on explosives. He does not pretend to experience or experiment, and, as he only presents the statements of others in readable form, whilst he has performed this task admirably, he could not be supposed to know fact from falsehood, nor was he expected to controvert the latter.

Those who know Mr. Alfred Nobel, respect him for his enterprise, rather than for his courage or his chemical acquirements. As a projector of companies to exploit his patents, he must drift with the tide of public opinion; when the prejudices aroused by the accidents that occurred to his manufacture of nitro-glycerin shall have subsided, doubtless he will be as ready to return to his early love, nitro-glycerin, as he now is to bask in the favors of his present mistress, dynamite.

In a paper read before the Engineer's club of St. Louis, April first, 1874, Mr. Robert Moore, C. E., said: "My brother put a charge of nitro-glycerin into a can, immersed it in an exploder, and allowed the whole to freeze solid. He then burst the exploder, bursting at the same time the can, and scattering the nitro-glycerin unexploded in frozen lumps in all directions. Some of these lumps were gathered up, and by several blows of a hammer, during which they were melted, exploded on an anvil." In the same paper, the writer gives another interesting fact.

"During the summer of 1872, as my brother was grading a piece of railroad in Ohio, he found himself confronted with a mile or more of very dense forest, in which, as the grade line was near the surface, the whole road bed had to be grubbed. Many of the trees were very large, and the largest, an oak of about five feet in diameter, "had been cut around, leaving its immense stump in a condition which made it almost unmanageable. Even when entirely loosened, it was a question if oxen enough could be found to move it. Time was pressing, and labor of every kind, either men or teams, was very scarce. After some correspondence with Mr. Mowbray, of North Adams, Mass., he sent out a man with some sixty pounds of nitro-glycerin to make the experiment. It was so successful in doing rapidly what was wanted that a second and large consignment was brought on. Every stump was so shattered by it, that their removal seemed an easy task. And in some cases, where a deep trench was first dug about the roots, and the charge or charges introduced near the ground, the stumps were lifted entirely out of the ground and split into several pieces."

Professor George F. Barker of the College of Pennsylvania, assisted by Professor S. W. Johnson, professor of analytical and agricultural chemistry in Yale college, assisted at my request at some experiments, May seventeenth, 1870, at North Adams, by exploding upon two occasions a quantity of nitro-glycerin in an open saucer with great violence, by simple concussion, the fulminate cap used as an exploder being suspended above the surface of the nitro-glycerin in the saucer, and distant nearly two inches from it; so that the application of heat and pressure, or either of these agencies, is not necessary, as claimed by Nobel and others. In another experiment, made to set at rest any dispute as to the error of the assertion that heat or pressure are necessary, three tubes, closed at bottom and containing half an ounce of nitro-glycerin each, were placed *in water*, in a tumbler, being supported an inch from the bottom. Into the water in the tumblers, and outside of the tubes, distant from them nearly an inch, the fulminate cap was put. This was then fired, and caused the explosion of the nitro-glycerin through the intervening water. In the last experiment tried, using a tub of water, in which five tubes containing nitro-glycerin (half an

ounce in each) were suspended, distant four or five inches from each other, the fulminate cap being inserted in the middle tube, on firing this cap, the nitro-glycerin in all the tubes was exploded, as judged from the violent effects produced, the tub being smashed down on to the rock supporting it, the staves torn off at the upper hoop, and blown out from the lower hoop, and the water sent up, so as to return in a shower of mist; thus the fact on which A. Nobel claimed his title to a patent, viz., that he had discovered that nitro-glycerin was practically impossible to explode, except when confined, was proved to have been a mistaken notion.

To conclude: There are two points having a personal bearing, which I should be ungrateful to pass unnoticed: first and foremost the invariably prompt payment by the contractors of the Hoosac tunnel for supplies, amounting to over one hundred thousand dollars a year during the past four years, never delaying a day nor discounting a cent. This enabled me to confront litigation promptly, to meet heavy and extraordinary outlays, whether for legal advice, scientific opinions, continuous costly experiments, and new machinery to prevent accident, or overcome imperfections in working. It further enabled me to resist the audacious attempt to appropriate the discovery which Sobrero had given to mankind. And it is remarkable, that to the attacks of my competitors, I owe in a great measure what success I have achieved, for I could not have accomplished in twenty years what I have in six, except for the persistent efforts made to crush me; because these compelled me to study thoroughly every detail that had been previously attained in blasting, knowing, as I did, that any false step would be availed of, that litigation would be used as a scare (although it did not scare any at all), that any accident, either in the factory, on the road, or in the mine, would be blazoned as the crime of the nitro-glycerin-maker; all these circumstances begat a resolution to anticipate every contingency, to be ever watchful and closely observant,—in fine, attacks have been to me "a blessing in disguise," in view of the sleepless, watchful, untiring attention to my business and its details which these attacks provoked.

CHAPTER VII.

COLONEL PASLEY'S SYSTEM OF SUBMARINE BLASTING—ELEMENTS NECESSARY TO SUCCESS—STATIC ELECTRICITY FOR BLASTING—INDUCTION COILS—ELECTRO-DYNAMIC MACHINES: SIEMENS, LADD, FARMER AND GRAMME—ELECTRO-MAGNETIC: WHEATSTONE, A. N. BREQUET—THE AUSTRIAN EBONITE FRICTIONAL PLATE MACHINE—RITCHIE & SONS' COIL FIRES TWO HUNDRED AND FIFTY MINES—SUMMARY ABSTRACT OF THE VARIOUS BATTERIES—PRACTICAL OBJECTIONS TO THE PRESENT FORM OF EBONITE PLATE MACHINES—CAUSES OF THEIR DETERIORATION BY USE—INSUFFICIENT ELECTRIC FORCE LEADS TO DANGEROUSLY SENSITIVE EXPLODERS—A NEW FORM OF CYLINDER FRICTION MACHINE—ITS ADVANTAGES ENUMERATED—PURE GUTTA-PERCHA THE BEST INSULATOR FOR WIRES—POWERFUL EXPLODERS TRUE ECONOMY—GUTTA-PERCHA INSULATED EXPLODERS—CONCLUSION.

HALF a century has passed since Colonel Pasley first blasted by means of electricity, in the submarine operations of removing the Royal George, sunk at Spithead. The system adopted by Pasley, was the interposing an exceedingly fine platina (iron, or an alloyed metal will answer) wire in the path of a current of electricity from a powerful voltaic battery, the resistance offered by the diminished conducting power of the fine wire to the passage of the electric current heating the wire to redness and thereby exploding the charge. The ele-

ments necessary to success in this system, consist in the means of developing a large *quantity* of voltaic or magnetic electricity, sufficient area of conducting and return wires, and sealing the fine wire that is heated, within the charge to be exploded.

Another system of blasting by electricity, depends upon a sudden discharge of static electricity between the terminals of two wires imbedded in a suitable priming composition (page seventy-four), which is thereby fired; and the elements necessary to success in this method, are: the means of exciting and accumulating static electricity, conducting and return wires, and a sealed priming compound that can be exploded by the passage of the spark between the terminal points, say of thirty pairs of wires. The apparatus suggested for exciting and accumulating the electricity, are: (*a*). A frictional electric machine, and Leyden jar. (*b*). A voltaic battery with induction coil. (*c*). An electro-dynamic machine, such as Siemens', Ladd's, Farmer's or Gramme's. (*d.*) An electro-magnetic machine, Wheatstone's, Brequet's, Saxton's, Clarke's, etc., etc.

(*a*). The first of these apparatus was reported upon by the Austrian commission in 1860, under Baron Abner, as fulfilling all the conditions necessary for mining operations, being portable, inexpensive, unaccompanied by any expenditure for acids etc., etc. I will briefly note the objections to the others and then revert to the Austrian or frictional plate machine, because the latter, in a modified form, has been used at the Hoosac tunnel throughout.

(*b*). In May, 1872, Messrs. Ritchie & Sons, of Boston, constructed, at my request, three varieties of induction coils, and, in the course of a long series of experiments, I discovered some interesting details, enabling me to fire *two hundred and fifty mines* at each break of connection. Since, however, these machines are too costly for contractor's work, being better adapted for any important operation, where the infallible discharge of a large number of mines would justify the outlay, a detail of these experiments and their valuable results must be omitted for want of space.

(*c*). This class of machines are all effective enough, but they diminish rapidly in power in the mine, and for submarine blasting, especially at long distances, and they are costly.

(*d.*) M. A. N. Brequet, of Paris, has constructed a machine of the electro-magnetic class, which he terms an Exploder, to fire four or five of the Abel fuses at one break of contact; but, in a tunnel, or for submarine work, it loses force. Mons. B. believed he could, by introducing the Jamin magnet, increase the power of these machines so as to fire twenty of the Abel fuses, and I placed with him the funds to cover such a machine, in September, 1873. It is now May, 1874, and, as I find the old pattern machine has been shipped to a friend of mine, whilst I have no advice of any shipment of an improved pattern, I conclude that he has not yet succeeded in constructing a machine to come up to his anticipations. The "Wheatstone exploder" fires five charges simultaneously; any number beyond that, must be arranged in separate series as suggested by Verdu and Savare, involving a proportionate number of leading and return wires. This is not suited to tunnel or submarine work, where (the former especially) twelve to thirty holes must be fired at once, and injury to the various series of leading and return wires would be expensive, and could not be avoided.

To return, then, to the frictional electric machine. When in good order the ebonite plate frictional electric machine or Austrian battery, as modified by H. J. Smith, of Boston, will fire twenty or thirty holes, at one discharge, and this at a distance of four or five hundred feet in a wet tunnel, but they so rapidly deteriorate, owing to faulty details, that the delay in returning them to, and awaiting their return from the maker, is troublesome, expensive and disappointing. After a week's use, the exciting plate, when worked in a dark room, without the casing, shows electricity leaping all over the plate. This is caused by specks of amalgam from the rubber. Fine particles of this amalgam are scattered throughout the case, and these assist in dissipating the force. The surface of the exciting plate becomes scratched or furrowed by the serrated edges of the collector, and the variation in rapidity of exciting a charge is so great after a month's use, that a blaster, with a new machine in perfect order, incautiously taking the same number of turns as with his old battery, and nervously determined to make sure fire, is apt to perforate the condenser. At one time this deterioration was so troublesome that the day of rest was devoted

to battery cleaning, drying and remounting. It has the further effect of tempting the men to prefer a very sensitive exploder, dangerously so, as the readiest remedy for deficient electric force; "the priming cannot be too sensitive," was once remarked in view of the loss of time, and delay of the work by these mis-fires. If the reader will imagine the disappointment and vexation of a blaster, when several of his charges have missed fire, to say nothing of the risk of approaching the heading of a tunnel to re-connect his leading and return wires, conscious of the impatience of sixteen men waiting to resume their work, he will be able to appreciate the value of a machine, that will continue to perform its work, from day to day and week to week, without expense and anxiety. Under the influence of these impressions, and instructed by the constant return of these machines for repair, I have endeavored to avail of this experience in overcoming the preceding objection, without touching the "patent rights" of present makers. To this end I have constructed, a cylinder electric machine, for which the following advantages are claimed:

1. I selected the cylinder for an exciting surface, because, says Hearder, in the Phil. Mag. vol. xv, p. 290, "The cylinder machines have a superiority in their exciting power over plate machines of equal surface, in the proportion of four to one."

2. The rubber is so constructed as to avoid fouling the exciting surface by the amalgam.

3. The collector cannot scratch or furrow the exciting surface.

4. Should the operator, under nervous excitement of firing, reverse the crank violently, no damage ensues.

5. The condensing surface is capable of taking up five times the quantity of electricity, of the present plate machine, so that risk of perforation is diminished in the ratio of five to one.

6. Should either of the plates of which the condenser is composed, be perforated by any chance, it can be removed, and replaced, without loss of the whole.

7. Provision is made (for the first time), to absorb any moisture that may possibly get within the case, so that time cannot impair the action of the machine.

8. Except the heads of the screws which bind the case together and serve as a protection to the case, there are no projecting knobs, and the devices for attaching the leading and return wires to the machine, it is believed, will commend approval.

9. A ground connection is added, with a view to more rapid charge.

10. A simpler and cheap modification of the machine is constructed so as to discharge itself at the precise moment when a sufficient amount of electricity is accumulated to perform the work allotted, be it more or less, for contractors' use.

I believe the new battery will, under every condition of the atmosphere, whether damp, or rarefied, evolve, at the will of the operator, abundance of electricity, possessing the property of leaping thirty solutions of continuity and developing heat enough to fire a perfectly safe priming. It is portable, weighing twenty-six pounds, durable, and *retains its efficiency* under adverse conditions, as thoroughly as in the workshop, and it now remains for those engaged in electrical blasting to give their verdict, for inventors are but partial judges of their own bantlings.

One word as regards the gutta-percha insulated leading wire, and return wire, and the insulated wire exploders. The approval of those who have tried them entirely satisfies my ambition. I have been again and again tempted to adulterate the gum with pitch, a magnesian carbon, dry clay, or plaster of Paris, with a view to extend their sale by cheapening their cost, but I have preferred a moderate *clientelle* to a large business, to be obtained at the risk of the operator's life. I have insisted, in the former editions of this work, on the necessity of using a heavy charge of fulminate of mercury, in order to effect the initial explosion, so as to develop completely the full force of nitro-glycerin, mica blasting powder, and gun cotton. This view has been confirmed in the Hoosac tunnel work, most emphatically. The so-termed giant powder was found to be "of no account" until an initial violent explosion of nitro-glycerin was used with it, to start out its force. This is true economy and is confirmed by every scientific writer who has experimented on the subject. To this end, I have perfected a new electric exploder, which secures perfect immunity from water, vapor, heat and shock of adjacent explosives, is unfailing, and contains

a charge of fulminate of mercury that ensures the full development of the explosive force of either tri-nitro-glycerin, mica blasting powder, gun cotton, or the dynamites; nor can the priming be fired by uncondensed electricity, that is, by the electric state of the atmosphere. These properties were fully tested on the sixth of March, 1874, when an explosion of giant powder in the room adjoining the time-keeper's office at the West shaft, destroyed the building, wherein a quantity of these exploders were suspended immediately over the giant powder, and were blown out with the rafters, roof and sides of the building. The gutta-percha which served to insulate both wires and the fulminating capsule, was heated to stickiness, by the resistance offered to the exploding gases, from the walls, roof and floor of the room, yet there was no injury done either to the insulated wires or the continuous envelope of gutta-percha surrounding the fulminating cap, which envelope preserved them from the flame, heat and shock of the explosion in the confined space. The safety of these exploders was here emphatically demonstrated, and the provision against accidents of this kind, justified by the result. The few cents' difference in cost between cotton-covered wire dipped in beeswax and resin for insulation, with its naked copper capsule,—the present form of cheap exploder, and these perfected exploders, above described, will be found a moderate insurance against mis-fires and accidents. These details may seem wearisome, but the casualties of blasting can only be averted by using materials absolutely reliable; should the reader be engaged in the task of harnessing up together those subtile, evasive, terrific forces—electricity, electric fuse priming, fulminate of mercury and nitro-glycerin, for the convenience of his fellow-man, he will comprehend the writer's earnestness, and agree with him, that his motto should be, "*Aut nunquam tenta aut perfice.*"

INSTRUCTIONS FOR HANDLING AND USING MOWBRAY'S TRI-NITRO-GLYCERIN.

1. Handle carefully, avoiding a sudden jar or concussion, and be very careful, if any is spilt outside the can, to avoid striking it against any hard substance.

2. When solid, thaw out by placing the cans in a tub of warm water, not hotter than the wrist can bear, first pouring warm water into the can, and always remove the can before adding more hot water to the tub.

3. To fill Cartridges, &c.: Hold the Cartridges to be filled over a tray, say two feet by three feet, the bottom of which should be covered with plaster of Paris (which will not readily explode when saturated with nitro-glycerin). The soiled plaster of Paris should be frequently renewed.

4. If the nitro-glycerin in a liquid state is kept in store or magazine for some time, the cork should be loosely inserted, and a pint of cold water poured into each can, to be frequently poured off and replaced with fresh cold water in warm weather, taking care to retain the bladder under the cork. It is preferable, when ice can be procured, to congeal the nitro-glycerin.

5. Use funnels (gutta-percha, if they can be had) for filling

water holes. Under no circumstances whatever attempt to tamp the drill holes; it is unnecessary, and may kill the man who attempts it.

6. Hot irons to warm the water, or for soldering the cans, will be sure to cause explosions.

7. Never sledge or attempt drilling in a hole or seam where nitro-glycerin has been spilled; fire an exploder, which will effectually clear it up.

8. Never pour nitro-glycerin into a hole unless perfectly sure that it is a sound hole, or will hold water; if seamy always use cartridges.

9. To obtain the best results with nitro-glycerin, drill deep holes, six feet or more. Use powerful exploders and well insulated wires. It is cheaper to fire by electric battery with simultaneous explosion, than to fire several holes with tape fuse.

10. Look out after a blast for any unexploded cartridges lying around.

11. Never allow any but the most careful persons to handle or have charge of the nitro-glycerin, and insist upon the use of every precaution to prevent an accident or explosion.

12. Never allow empty glycerin cans to be used for any other purpose, but destroy them by a fuse and exploder, or by building a fire under them, first, however, removing them to a safe distance.

13. Examine your cans from time to time, and notice if, at the level of the nitro-glycerin, any pin-holes have eaten through; in such case procure a new can, or stone jar, and empty the contents out, not trusting your hold to the upper part of the can, lest it may give away.

14. When solid, or congealed, it is absolutely safe; if possible, therefore, any surplus should be stored surrounded with ice, since no explosion can take place when it is solid.

GEORGE M. MOWBRAY.

North Adams, Mass., June, 1874.

Mr. Wederkinch, late assistant engineer in charge of the Central shaft division of the Hoosac tunnel, and now engineer in chief of the Sutro tunnel, Virginia city, Nevada, furnished the subjoined data, for the month of September, 1872:—

Progress of heading going eastward from Central shaft has been from station 11,709 to station 11,604, or one hundred and five lineal feet.

The excavation averages about eight feet high and twenty-four feet wide; 781.95 cubic yards of rock have been removed by two thousand five hundred and sixteen pounds of tri-nitro-glycerin, filled into two thousand five hundred and sixty-six feet and ten inches of tin cartridges, of one and three-eighths inches diameter, or 3.217 or 3 1-5 pounds of tri-nitro-glycerin used per cubic yard of rock.

Between six and seven drilling machines, mounted on two carriages, have been used for boring, using two miners for each machine.

Aggregate amount of work done, 1,554 shifts by miners, and 1,212 shifts by rockmen, each shift of eight hours' duration.

Total length of holes drilled for fourteen cuts, has been 139 feet, making 9 93 feet per cut, equal to 9.12 feet on a straight line; each cut averaged 7.5 feet, leaving 1.61 feet in bottom, showing 82 1-2 per cent. of actual work performed in blasting during 14 consecutive cuts; all side holes drilled with judgment have been blasted to bottom.

The following detailed statement shows number, and depth in feet, of holes drilled; amount of tri-nitro-glycerin in feet and inches used for each hole; time, and whole amount of tri-nitro-glycerin used at each blast, etc., etc.:

DATE. 1872.	Time of Shift.	Time of Blast.	Name of Foreman.	Time used in drilling & removal of rock.	Number of holes.	Number and depth of the holes in feet.	Cartridges & number feet tri-nitro-glycerin in same.	Whole am'nt of tri-nitro-glycerin used in blast.	Position of Holes.	REMARKS.
								FEET.		
September 2d.	3—11									No blast.
September 3	11—7	2 a. m.	Papan	11	12	9 1-2	6—5f. 8in.			
							6—7 4			
							6—1 10			
							2—3 8	96 1-3	Cut	Re-blasted eight holes.
	7—3	2 p. m.	Stevens	12	15	10—9	10—2 10			
						5—5	5—1 10	37 1-2	Sides	
	3—11	11 p. m.	Knucky	9	23	20—8	20—2 4			
						3—3 1-4	3—1	49 2-3	Sides	
September 4	11—7									No blast.
	7—3	1 p. m.	Stevens	14	6	3	6—1 6	9	Sides	
	3—11									No blast.
September 5	11—7	2 a. m.	Papan	13	12	9	6—5 8			
							6—7 6			
							10—2 6	104	Cut	Re-blasted ten holes.
	7—3	12 m.	Stevens	10	13	9	13—2 10	37 2-3	Sides	
	3—11									No blast.
September 6	11—7	1 a. m.	Papan	13	10	8 1-2	10—2 10	28 1-3	Sides	
	7—3	12 m.	Stevens	11	13	8	13—2 10	37 2-3	Sides	
	3—11									No blast.

DATE. 1872.	Time of Shift.	Time of Blast.	Name of Foreman.	Time used in drilling & removal of rock.	Number of holes.	Number and depth of the holes in feet.	Cartridges & number feet tri-nitro-glycerin in same.	Whole am'nt tri-nitro-glycerin used in blast.	Position of Holes.	REMARKS.
September 7	11—7	6 a. m.	Papan	18	12	11	12—7f. 6in.	90	Cut	
	7—3									No blast.
	3—11	4 p. m.	Knucky	10	11	9	11—2 10	31 1-6	Sides	
September 8	11—7	1 a. m.	Knucky	9	20	8	20—4	80	Sides	
	7—3									Sunday.
	3—11									Sunday.
September 9	11—7	11 p. m.	Papan	6	12	5	12—2 6	30	Sides	
	7—3	8 a. m.	Stevens	9	12	10	12—7	84	Cut	
	3—11	7 p. m.	Knucky	11	12	9	12—3	36	Sides	
September 10	11—7									No blast.
	7—3	7 a. m.	Stevens	12	23	8	23—2 10	65 1-6	Sides	
	3—11									No blast.
September 11	11—7	3 a. m.	Papan	20	12	10	12—7	84	Cut	
	7—3									No blast.
	3—11	6 p. m.	Knucky	15	12	8	12—4	48	Sides	
September 12	11—7	6 a. m.	Papan	12	18	12—8	12—3			
						6—5	6—1 6	45	Sides	
	7—3	3 p. m.	Stevens	9	9	7	9—1 4	12	Sides	
	3—11									No blast.
September 13	11—7	2 a. m.	Papan	11	12	10	12—6 8	80	Cut	
	7—3									No blast.
	3—11	3 p. m.	Knucky	13	16	9	16—2 10	45 1-3	Sides	
September 14	11—7	3 a. m.	Papan	12	16	8	16—2 10	45 1-3	Sides	
	7—3	11 a. m.	Stevens	8	6	7	6—2 10	17	Sides	
	3—11									No blast.
September 15	11—7									No blast.
	7—3									Sunday.
	3—11									Sunday.
September 16	11—7	11 p. m.	Knucky	20	12	10	7—6			

							5—7 6	41	Cut	
	7—3	10 a. m.	Papan	11	23	8	23—2 10	65 1-6	Sides	
	3—11									No blast.
September 17	11—7									No blast.
	7—3	7 a. m.	Papan	21	16	6 1-2	16—2 6	40	Sides	
	3—11									No blast.
September 18	11—7	12 m.	Knucky	17	12	10 1-2	6—7 6			
							6—6	81	Cut	
	7—3	9 a. m.	Papan	9	12	9	12—2 10	34	Sides	
	3—11									No blast.
September 19	11—7	6 a. m.	Knucky	21	25	7	25—2 8	66 2-3	Sides	
	7—3	10 a. m.	Papan	4	3	4	3—2	6	Roof	
	3—11	7 p. m.	Stevens	9	12	10	12—5 8	68	Cut	
September 20	11—7	3 a. m.	Knucky	8	13	7	13—2 6	32 1-2	Sides	
	7—3									No blast.
	3—11	6 p. m.	Stevens	15	12	6	12—3	36	Sides	
September 21	11—7	12 m.	Knucky	6	11	7 1-2	11—2 10	31 1-6	Sides	
	7—3	3 p. m.	Papan	15	12	10	6—5 8			
							6—7 6	79	Cut	
	3—11	11 p. m.	Stevens	8	23	7	23—2 10	65 1-6	Sides	
September 22	11—7									No blast.
	7—3									Sunday.
	3—11									Sunday.
September 23	11—7									No blast.
	7—3	1 p. m.	Stevens	22	12	9	6—5 8			
							6—7 6	79	Cut	
	3—11	11 p. m.	Knucky	10	12	8	12—2 10	34	Sides	
September 24	11—7									No blast.
	7—3	9 a. m.	Stevens	10	14	8	14—2 10	39 2-3	Sides	
	3—11	8 p. m.	Knucky	11	15	7	15—2 6	37 1-2	Sides	
September 25	11—7									No blast.
	7—3	11 a. m.	Stevens	15	12	10	6—5 8			
							6—7 6	79	Cut	
	3—11	10 p. m.	Knucky	11	12	8	12—2 10	34	Sides	
September 26	11—7	7 a. m.	Papan	9	14	8	14—2 10	39 2-3	Sides	
	7—3									No blast.

DATE. 1872.	Time of Shift.	Time of Blast.	Name of Foreman.	Time used in drilling & removal of rock.	Number of holes.	Number and depth of the holes in feet.	Cartridges & number feet tri-nitro-glycerin in same.	Whole am'nt tri-nitro-glycerin used in blast.	Position of Holes.	REMARKS.
September 7	11—7	6 a. m.	Papan	18	12	11	12—7f. 6in.	90	Cut	
	7—3									No blast.
	3—11	4 p. m.	Knucky	10	11	9	11—2 10	31 1-6	Sides	
September 8	11—7	1 a. m.	Knucky	9	20	8	20—4	80	Sides	
	7—3									Sunday.
	3—11									Sunday.
September 9	11—7	11 p. m.	Papan	6	12	5	12—2 6	30	Sides	
	7—3	8 a. m.	Stevens	9	12	10	12—7	84	Cut	
	3—11	7 p. m.	Knucky	11	12	9	12—3	36	Sides	
September 10	11—7									No blast.
	7—3	7 a. m.	Stevens	12	23	8	23—2 10	65 1-6	Sides	
	3—11									No blast.
September 11	11—7	3 a. m.	Papan	20	12	10	12—7	84	Cut	
	7—3									No blast.
	3—11	6 p. m.	Knucky	15	12	8	12—4	48	Sides	
September 12	11—7	6 a. m.	Papan	12	18	12—8	12—3			
						6—5	6—1 6	45	Sides	
	7—3	3 p. m.	Stevens	9	9	7	9—1 4	12	Sides	
	3—11									No blast.
September 13	11—7	2 a. m.	Papan	11	12	10	12—6 8	80	Cut	
	7—3									No blast.
	3—11	3 p. m.	Knucky	13	16	9	16—2 10	45 1-3	Sides	
September 14	11—7	3 a. m.	Papan	12	16	8	16—2 10	45 1-3	Sides	
	7—3	11 a. m.	Stevens	8	6	7	6—2 10	17	Sides	
	3—11									No blast.
September 15	11—7									No blast.
	7—3									Sunday.
	3—11									Sunday.
September 16	11—7	11 p. m.	Knucky	20	12	10	7—6			

							5—7 6	41	Cut	
	7—3	10 a. m.	Papan	11	23	8	23—2 10	65 1-6	Sides	
	3—11									No blast.
September 17	11—7									No blast.
	7—3	7 a. m.	Papan	21	16	6 1-2	16—2 6	40	Sides	
	3—11									No blast.
September 18	11—7	12 m.	Knucky	17	12	10 1-2	6—7 6			
							6—6	81	Cut	
	7—3	9 a. m.	Papan	9	12	9	12—2 10	34	Sides	
	3—11									No blast.
September 19	11—7	6 a. m.	Knucky	21	25	7	25—2 8	66 2-3	Sides	
	7—3	10 a. m.	Papan	4	3	4	3—2	6	Roof	
	3—11	7 p. m.	Stevens	9	12	10	12—5 8	68	Cut	
September 20	11—7	3 a. m.	Knucky	8	13	7	13—2 6	32 1-2	Sides	
	7—3									No blast.
	3—11	6 p. m.	Stevens	15	12	6	12—3	36	Sides	
September 21	11—7	12 m.	Knucky	6	11	7 1-2	11—2 10	31 1-6	Sides	
	7—3	3 p. m.	Papan	15	12	10	6—5 8			
							6—7 6	79	Cut	
	3—11	11 p. m.	Stevens	8	23	7	23—2 10	65 1-6	Sides	
September 22	11—7									No blast.
	7—3									Sunday.
	3—11									Sunday.
September 23	11—7									No blast.
	7—3	1 p. m.	Stevens	22	12	9	6—5 8			
							6—7 6	79	Cut	
	3—11	11 p. m.	Knucky	10	12	8	12—2 10	34	Sides	
September 24	11—7									No blast.
	7—3	9 a. m.	Stevens	10	14	8	14—2 10	39 2-3	Sides	
	3—11	8 p. m.	Knucky	11	15	7	15—2 6	37 1-2	Sides	
September 25	11—7									No blast.
	7—3	11 a. m.	Stevens	15	12	10	6—5 8			
							6—7 6	79	Cut	
	3—11	10 p. m.	Knucky	11	12	8	12—2 10	34	Sides	
September 26	11—7	7 a. m.	Papan	9	14	8	14—2 10	39 2-3	Sides	
	7—3									No blast.

DATE. 1872.	Time of Shift.	Time of Blast.	Name of Foreman.	Time used in drilling & removal of rock.	Number of holes.	Number and depth of the holes in feet.	Cartridges & number feet tri-nitro-glycerin in same.	Whole am'nt tri-nitro-glycerin used in blast.	Position of Holes.	REMARKS.
	3—11	3 p. m.	Knucky	8	12	8	12—2f. 10in.	34	Sides	
September 27	11—7	5 a. m.	Papan	14	12	10	6—5 8			
							6—7 6	79	Cut	
	7—3	3 p. m.	Stevens	10	12	9	12—2 10	34	Sides	
	3—11	11 p. m.	Knucky	8	23	9	23—2	65 1-6	Sides	
September 28	11—7									No blast.
	7—3									No blast.
	3—11	6 p. m.	Knucky	19	12	10	6—5 8			
							6—7 6	79	Cut	
September 29	11—7									No blast.
	7—3									Sunday.
	3—11									Sunday.
September 30	11—7	12 m.	Papan	14	12	8	12—2 6	30	Sides	
	7—3	9 a. m.	Stevens	9	12	7	12—2 10	34	Sides	
	3—11									No blast.
October 1st	11—7									No blast.
	7—3	10 a. m.	Stevens	25	12	7	12—2 6	30	Sides	

As we proceed the rock has gradually been changing to a somewhat harder, closer, and more even-grained nature, favorable both to drilling and blasting, breaking the blasted rock into smaller pieces, rendering unnecessary the derrick or block-holing. In the month of October, 1872, the progress of heading was 132 lineal feet, 987.30 cubic yards of rock were removed by 2,822 lbs. of tri-nitro-glycerin, using 2.858 lbs. per cubic yard of rock. For November, 1872, the progress was 148 lineal feet, 1,160.34 cubic yards of rock were removed by 3,256 lbs. of tri-nitro-glycerin, using 2.806 lbs. per cubic yard of rock.

On December twelfth, 1872, an opening was made through to the East end, and work was soon re-commenced by the same force on the heading going west from the Shaft, which had been stopped for some time on account of the numerous water-bearing seams that had previously been met with, giving over two-hundred gallons of water per minute, to be raised up the Shaft, a distance of 1,028 feet.

The rock in this heading, going west from the Shaft, is very hard, close-grained and even, in looks very much resembling granite; the dip, when any, is east, about the same as the other heading, but, as the direction of working is reversed, the rock lies more favorably. The progress of this heading in January, 1873, was 144 lineal feet; 1,300.86 cubic yards of rock were removed by 2,513 lbs. of tri-nitro-glycerin, using 1.931 lbs. of tri-nitro-glycerin per cubic yard of rock.

About the middle of January, 1873, work was re-commenced at the bench enlargement going east from the Shaft, and here 829.98 cubic yards were removed by 534 lbs. of tri-nitro-glycerin, using 0.644 lb. of tri-nitro-glycerin per cubic yard of rock.

APPENDIX.

The early literature of nitro-glycerin, bears a remarkable sameness, probably owing to the fact, that it generally heralded the establishment of a company, with large capital. I here copy an introductory extract from the prospectus of the United States Blasting Oil Company, published in 1866, showing the assumption (repeated in an article published in the Troy *Times*, 1874) that Nobel invented nitro-glycerin. This prospectus is headed :—

NOBEL'S BLASTING OIL.

"For more than four centuries the common gunpowder, invented by the somewhat mysterious monk, *Barthold Schwarz*, was the only explosive chemical compound used for the purpose of hunting, warfare and mining. Although science and practical experiments have brought forward successive perfections in its manufacture, only very slight changes took place in its original combination of nitre, sulphur and charcoal.

"It was reserved to our century, and due to the wonderful progress of the science of chemistry in the last twenty years, that this old established contrivance has been superseded by more powerful chemical agents, as the old mail stages have been superseded by locomotive and rail car, and clumsy sailing vessels by fleet steamers. A *modern Barthold Schwarz* was born, who, not as his grandsire, in the dark cell and alchemical kitchen of a convent, but in the sun-beamed laboratory of chemical science, invented a compound, the explosive power of which *surpasses the power of gunpowder quite as much as the ball of a gun surpasses in swiftness and destructive power the dart of an Indian.*

"This man is ALFRED NOBEL, a Swedish chemist and a mining engineer, and his compound is called nitro-glycerin, deriving this name from its two principal constituents, nitre and glycerin."

If the reader will turn to page sixteen, it will be seen that Ascagne Sobrero discovered nitro-glycerin in 1846, and not A. Nobel; the latter (Nobel) merely formed joint stock companies such as the United States Blasting Oil Company, in 1866. The prospectus goes on to narrate that about five factories and some five companies were formed up to 1866, under these audacious misrepresentations, wherein this man of the "sun-beamed laboratory of chemical science," etc., etc.—

(*See Transportation of Nitro-Glycerin, page eighty-seven.*)

VOYAGE OF SLOOP "MIST."

TROY, N. Y., MONDAY, Oct. 7, 1872.

Loaded with five thousand one hundred and three and one-fourth pounds of nitro-glycerin at Walsh's wharf.

TUESDAY, Oct. 8.

7 A. M. Under way for New York with boy and captain, one hand having left, scared.

SATURDAY, Oct. 12.

Arrived at New York. Wind foul, so anchored forty-eight hours over Sunday.

MONDAY, Oct. 14.

7 A. M. Wind fair. Weighed and made sail. Unable to get another hand, so concluded to make trip with boy and self only.

TUESDAY, Oct. 15.

5 P. M. Sighted Hog Island Light. Wind fair. A little after 5 P. M., say 5:30, wind shifted to south-west with squalls and rain. Gradually settled down to strong south-westerly breeze.

9 P. M. Wind increasing, with heavy head sea. Vessel behaving well, but pitching heavily. Shipped heavy sea, part of which found its way below. A gale, so at 9:30 P. M. up helm and ran before it, hoping to make Delaware breakwater for shelter.

WEDNESDAY, Oct. 16.

2. A. M. Heavy following sea. Wind increasing. Failed to make Delaware breakwater for shelter. Stood out to sea for offing and hove to. During this storm split foresail badly. Heavy sea, sweeping craft fore and aft.

THURSDAY, Oct. 17.

Daylight. Wind decreasing very fast and sea moderating. Made sail for Richmond. Mainsail and balloon jib.

FRIDAY, Oct. 18.

Light southerly winds and smooth water.

SATURDAY, Oct. 19.

All day light head winds. In evening made Hampton Roads and brought up.

SUNDAY, Oct. 20.

At anchor off Fortress Monroe, Hampton Roads. In evening, about 6 P. M., weighed and proceeded up the James River under sail. Mainsail and balloon jib.

TUESDAY, Oct. 22.

Brought up at City Point, 5 P. M. Telegraphed Mr. Benson, Mowbray's messenger, at Richmond, to have teams ready to load on cars.

WEDNESDAY, Oct. 23.

Made arrangements for tow with tug Portland, on Thursday morning.

THURSDAY, Oct. 24.

Tug failed me. Lay at City Point all day.

FRIDAY, Oct. 25.

Received telegram from Mr. Benson, asking when I should be up; if not before morning would come down. Telegraphed him to come down.

SATURDAY, Oct. 26.

9 A. M. Mr. Benson arrived, examined cargo, found all right; and, as no chance of tow, advised that rumors were afloat as to cargo, and started me up under sail at 12 A. M. Noon, with ebb tide and light wind. 4 P. M. Tide good; flood and light wind; proceeding slowly. 10 P. M. Picked up by stray tow-boat.

SUNDAY, Oct. 27.

2 A. M. Arrived at Richmond. 11:30 P. M. Started to break out cargo. Wind fine but very dark.

MONDAY, Oct. 28.

2 A. M. Loaded first team. 7 A. M. Discharged completely. 11 A. M. Received balance of freight money, $550.

RAPP. BURNS, Skipper.

EFFECT OF HIGH TEMPERATURES ON NITRO-GLYCERIN.

Many writers have stated that nitro-glycerin explodes at 356° F. M. P. Champion did not find this to be the case. M. Leygue designed an apparatus by means of which M. Champion prepared the following table, giving the various changes at different temperatures to which nitro-glycerin may be subjected:

365° F. boils, volatilizes with disengagement of yellow vapor.
381° F. evaporates slowly.
392° F. evaporates rapidly.
422° F. deflagrates violently.
442° F. deflagrates lively.
465° F. detonates with difficulty.
494° F. detonates very perfectly and violently.
512° F. detonates feebly.
548° F. detonates feebly with flame.

At a dark red heat nitro-glycerin assumes the spheroidal state and evaporates without explosion.

TEMPERATURE AT WHICH CERTAIN EXPLOSIVE SUBSTANCES BURN OR DETONATE.

Powder used in the Chassepot rifle,	380° F.
Fulminate of mercury,	392° F.
Mixture equal parts sulphur and chlorate potash,	392° F.
Abel's gun cotton, compressed,	400° F.
Gun cotton, loose,	428° F.
Sulphur burns in air,	475° F.
Nitro-glycerin explodes,	493° F.
Sulphuret antimony 1 part, chlorate potash 1 part, explodes,	536° F.
Sporting gunpowder,	540° F.
Cannon gunpowder,	563° F.
Picrate of mercury, picrate of lead, picrate of iron,	565° F.
Designolle's torpedo powder (picrate), artificial saffron,	600° F.
Picric acid, picrate of magnesia, picrate ammonia, picrate of potash,	605° F.
Musket picrate powder,	610° F.
Cannon powder quickened by picrate,	716° F.

PATENTS FOR EXPLOSIVES, ETC.

68,055,	Jabez B. Dowse,	Sensitive Priming.
76,499,	George M. Mowbray,	Manufacture of Nitro-Glycerin.
85,906,	Chester & Burstenbinder,	Manufacture of Nitro-Glycerin.
93,113,	G. M. Mowbray,	Exploding Nitro-Glycerin.
93,563,	H. J. Smith,	Electrical Machine.
93,752,	T. P. Shaffner,	Selenitic Powder.
93,753,	T. P. Shaffner,	Porifera Nitroleum.
93,754,	T. P. Shaffner,	Metalline.
94,819,	J. Dickey,	Torpedoes.
94,969,	G. M. Mowbray,	Purifying Nitric Acid.
96,465,	G. M. Mowbray,	Electric Priming.
97,241,	H. J. Smith,	Fuse Head.
98,854,	C. Dittmar,	Dualin.
99,069,	C. Dittmar,	Xyloglodine.
99,070,	C. Dittmar,	Apparatus for Xyloglodine.
104,217,	H. J. Smith,	Fuse Head.
106,606,	G. M. Mowbray,	Centrifugal Process for Nitro-Glycerin.
106,607,	G. M. Mowbray,	Centrifugal Apparatus for Nitro-Glycerin.
108,324,	Browne Bro's,	Fuse Head.
116,565,	D. Corgan,	Tamping.
117,577,	I. Taylor,	Nitro-Glycerin Can.
119,630,	C. E. Masten,	Rockets.
120,186,	J. Dickey,	Torpedoes.
120,438,	J. H. Holsey,	Blasting Plugs.
120,574,	J. Dickey,	Torpedoes.
120,862,	W. Curtis,	Gun Powder.
120,963,	E. Gomez,	Torpedoes.
121,783,	J. Holmes,	Squibs.
121,898,	E. A. L. Roberts,	Nitro-Glycerin.
122,245,	E. Gomez,	Explosive Compounds.
122,654,	E. A. L. Roberts,	Torpedoes.
122,688,	M. Ward,	Powder Kegs.

124,397,	G. M. Mowbray,	Assignee, Explosive Compound.
124,510,	R. Punshon,	Gun Cotton.
126,462,	G. James,	Fuses.
128,241,	G. M. Mowbray,	Electric Priming.
128,299,	A. Gotham,	Tamping.
128,416,	M. Newton,	Gun Cotton.
128,450,	J. B. Muschamp,	Explosive Substances.
128,945,	Browne Bro's,	Fuse Head.
130,123,	Fuchs & Clement,	Blasting Powder.
132,061,	S. Daddow,	Fuses.
133,040,	F. Lavallee,	Charging Drill Holes.
133,234,	P. Licht,	Rocket.
133,522,	L. Dupont,	Gun Powder.
134,438,	P. Oliver,	Gun Powder.
136,000,	C. Nelson,	Torpedoes.
137,196,	M. Gotham,	Torpedoes.
137,198,	A. Hamar,	Torpedoes.
137,439,	A. Hamar,	Nitro Glycerin.
137,440,	A. Hamar,	Nitro-Glycerin.
137,916,	A. Hamar,	Torpedoes.
138,373,	S. Briggs,	Torpedoes.
138,841,	T. S. Beach,	Explosive Compound.
139,452,	J. Burson,	Submarine Blasting.
139,468,	E. Judson,	Giant Powder.
139,686,	G. M. Mowbray,	Gutta-percha Fuse, Caps, etc.
139,738,	T. P. Shaffner,	Nitrated Gun Cotton.
139,746,	T. Varney,	Congealing Nitro-Glycerin.
141,455,	A. Nobel,	Explosive Compound.
141,585,	Norrbin & Ohlsson,	Explosive Compounds.
143,396,	S. Daddow,	Squibs for Blasting.
144,030,	A. Lamarree,	Portfires.
146,150,	N. Tenney,	Powder Kegs.
146,530,	W. N. Hill,	Explosive Compounds.
146,612,	L. Peck,	Torpedoes.
147,253,	G. Frisbee,	Plugs for Blasting.
147,254,	G. Frisbee,	Blasting.
147,872,	T. Shaw,	Cartridges.
148,338,	T. Varney,	Fuses.
148,674,	S. Daddow,	Squibs for Blasting.
150,428,	G. M. Mowbray,	Mica Blasting Powder.

REISSUES.

3,374,	T. P. Shaffner,	Tamping.
3,375,	T. P. Shaffner,	Tamping.
5,434,	E. A. L. Roberts,	Torpedoes.
5,759,	C. Dittmar,	Explosive Compounds.
5,773,	F. Burney,	Gun Powder.
5,798,	A. Nobel, (assigned)	Exploding Nitro-Glycerin.
5,799,	A. Nobel, "	Explosive Compounds.
5,800,	A. Nobel, "	Exploding Nitro-Glycerin.

Jl

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